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I have examined the Chemical Chart of Mr. E. L. Youmans, and am much pleased to say that it is a valuable means of readily imparting a correct knowledge of the nature of chemical combination. A variety of compounds are illustrated, so as to show at a glance their ultimate atomic constitution, in such a way as to impress it more forcibly upon the mind than could be effected by any other method with which I am acquainted. To those who are studying to obtain a knowledge of elementary and agricultural chemistry, as well as to all learners of chemical science, Mr. Youmans' Chart will render easily understood what might otherwise appear very difficult.

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I have hastily examined Mr. Youmans' new Chemical Diagrams, or Chart of chemical combinations by the union of the elements in atomic proportions.

The design appears to be an excellent one. It conveys to learners the idea of chemical combinations by connecting the elements by right lines with the compounds which they produce. Colored squares

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From DR. JOHN W. DRAPER, *Professor of Chemistry in the University of New York.*

Mr. Youmans' Chart seems to me well adapted to communicate to beginners a knowledge of the definite combinations of chemical substances, and as preliminary to the use of symbols, to aid them very much in recollecting the examples it contains. It deserves to be introduced into the schools.

From JAMES B. ROGERS, *Professor of Chemistry in the University of Pennsylvania.*

I cordially subscribe to the opinion of Professor Draper concerning the value to beginners of Mr. Youmans' Chemical Chart.

From W. F. HOPKINS, *Professor of Natural and Experimental Philosophy in the U. S. Naval Academy, Annapolis, Md.*

Having given to the Chemical Chart of Mr. E. L. Youmans such an examination as my small leisure permitted, I cheerfully state my conviction that its plan is admirably adapted to assist the teacher in communicating, and the learner in receiving, correct notions of the laws of chemical combination.

I commend it to the patronage of schools and academies where chemistry is taught, and shall immediately introduce it into the institution with which I am connected.

We have also examined Mr. Youmans' Chart, and very cheerfully concur in the foregoing opinion of Professor Hopkins.

JOHN TORREY,
Professor of Chemistry in the College of Physicians and Surgeons, New York.

WILLIAM H. ELLET,
Late Professor of Chemistry in Columbia College, S. C.

(SEE CLOSE OF THE VOLUME.)

A CLASS-BOOK

OF

CHEMISTRY,

IN WHICH

THE PRINCIPLES OF THE SCIENCE ARE FAMILIARLY EXPLAINED
AND APPLIED TO THE ARTS, AGRICULTURE, PHYSIOLOGY,
DIETETICS, VENTILATION, AND THE MOST IMPORTANT PHENOMENA OF NATURE.

DESIGNED FOR THE USE OF ACADEMIES AND SCHOOLS,
AND FOR POPULAR READING.

BY EDWARD L. YOUMANS,
AUTHOR OF "A NEW CHART OF CHEMISTRY."

> ——— To know
> That which before us lies in daily life
> Is the prime wisdom. MILTON.

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PREFACE.

THE present volume is designed as a popular introduction to the study of Chemistry. It aims to present the subject in such a manner as to win the attention and engage the interest of beginners, and is especially adapted to the wants of that large class, both in and out of school, who would like to know something of this interesting science, but have neither leisure nor opportunity to pursue it in a detailed and experimental way. As such will necessarily be more concerned to know what facts, principles, and results have been arrived at by chemical research, than to trace the routes by which they were reached, or the operations by which they may be confirmed, the following pages will be found chiefly occupied with the explanation of established principles, and their application to the most practical and familiar affairs of common life.

The department of Physics, which considers light, heat, electricity, and magnetism, has been left to Natural Philosophy, where it properly belongs and is always treated. Its introduction into Chemistry involves a repetition of topics in the two branches of study; and, in a volume of moderate size, it crowds out much useful matter which ought, on no account, to be spared. A knowledge of these agents is of course important to the chemical student, but so is that of mechanics and mathematics. In leaving each to its appropriate teacher, the example of some of our latest and best authorities has been followed. Descriptions of those chemical substances which are not frequently met with, as the rarer metals, are entirely omitted, and directions for making experiments have been much condensed. Experimental demonstrations, if not resorted to merely to captivate the senses by their alluring brilliancy, are highly useful; but they are always accompanied by the oral instructor, and should therefore, to a great extent, speak for themselves. It is entirely impossible in the present advanced state of the science, to embrace in a popular school-book both that information which learners generally require and also directions for a course of experiments sufficiently minute to be valuable. In order, for example, to unfold with any thing like clearness the august part which oxygen gas plays in the scheme of nature, it has been necessary to abridge the account of the various processes by which it may be prepared. Where experiments are given, the lecturer will supply this branch of instruction; where they are not to be had, it is superfluous.

Space has been thus afforded to consider the practical and useful applications of the science, in which all are interested, with greater fulness than is customary in text-books for schools. Organic Chemistry, both vegetable and animal, embracing much of agriculture, domestic processes, dietetics, the physiology of digestion and respiration, ventilation, the effects of alcohol upon the human system, and the relations of the vegetable and animal world to each other, and to the atmosphere, has been brought forward into that prominence which its obvious importance demands. If there should even be found repetition upon some of these points, the excuse must be a desire to impress certain great principles deeply upon the mind, rather than to encumber it with a mass of details, which, in most cases, are forgotten as quickly as they are acquired. By treating of familiar things, and presenting facts and truths alike valuable and entertaining, in a style free, as far as possible, from technicalities on the one hand and puerilities on the other, the author has endeavored to adapt the work to fireside reading as well as class-room study.

There is an idea prevalent that Chemistry is one of those dry and difficult subjects which belong exclusively to professors and lecture-rooms, and which cannot be invested with popular interest, or successfully taught as a branch of common education. How a science which gives law to nearly all the processes of human industry, connects its operations with our daily experience, involves the conditions of life and death, and throws light upon the sublime plan by which the Creator manages the world, can be regarded as lacking the elements of universal interest, it is not easy to imagine. That it is generally looked upon as difficult, may be readily accounted for. The science is so recent in its development, and chemists have been so much occupied in the field of original research, that but little has been done to popularize it. Books adapted to elaborate courses of

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INTRODUCTION.

The importance of a knowledge of Chemistry to each person, its value to various classes of society, and the necessity of making it a fundamental branch of popular education, will be apparent from the following considerations.

The physical system of every human being may be looked upon as a *chemical laboratory*, in which exactly the same kind of changes are carried on as are produced by the working chemist in his shop, and by means of similar instruments; the main difference being, that here, as elsewhere, the operations of art are coarse and bungling compared with the matchless perfection of nature. The chemist finds it necessary to dissolve all solid substances; that is, to bring them into the condition of fluids, in order to separate the various elements of which they may be composed. For a like reason, in order to separate the nutritious from the innutritious portions of food, it must first be dissolved or digested in certain cavities or vessels of the body, provided exclusively for the purpose. The chemist in his laboratory makes use of knives, rasps, and mortars, to cut, pulverize, and grind down the substances which he wishes to dissolve. The teeth in man perform a similar work; the incisors (front teeth) cut, the molars (double teeth) crush the food which is to be digested within the system. The principal substances which the chemist uses to bring solids into the state of solution are acids, such as vinegar and oil of vitriol; and alkalies, such as potash or soda. Precisely the same agents are employed by nature in the living laboratory. The juice of the stomach is acid, while that poured into the intestines is alkaline; and the class of foods which is not acted upon by one is dissolved by the other: in both cases that which is capable of forming blood is separated from that which is not. To aid and hasten chemical action, the operator stirs and agitates the mixtures in his vessels. For a similar purpose, to facilitate digestion, the food in the stomach is kept constantly in motion by a peculiar action of that organ.

This parallel may be much further extended by those who are acquainted with Chemistry and Physiology; showing that the animal system has for one of its great objects, to effect just the same kind of changes in matter which the chemist produces by artificial means.

Nor are the chemical operations of the living body carried on upon an insignificant scale; their *extent* is even more remarkable than the nice adaptations of the mechanism by which they are conducted. A man of average size, in the course of a single year, introduces into his system from eight to nine hundred pounds of solid food, above eight hundred pounds of oxygen gas, and three-fourths of a ton of water; making altogether upwards of three thousand pounds of matter. The solid and liquid elements contained in the blood are carried through the lungs by means of the great circulation at the rate of very nearly ten pounds per minute, which is equal to the enormous quantity of twenty-five hundred tons in the course of a year. The chief object of this perpetual circulation of the blood is to bring it into contact with atmospheric oxygen, by which it undergoes a very important chemical change. To effect this, no less a quantity than twelve thousand hogsheads of air are introduced into the lungs annually. Incredible as these statements may appear to those not familiar with the subject, they nevertheless rest upon numerous and accurate experiments, and are among the established facts of chemical physiology.

As man is thus, from necessity and by nature, a chemist, his bodily system being a chemical apparatus, and each act of eating, drinking, breathing, and digestion, a chemical experiment; and as this chemical action goes on at a rapid rate, involving the conditions of health and disease, and never ceasing for an instant from birth to death, it is certainly proper that he should understand something of a science of which he is himself so complete and wonderful an illustration. Few subjects can compare, either in interest or importance, with that which informs us of what our physical being is composed, the character and object of those remarkable changes which incessantly take place within us, and the nature of our relations to the surrounding world. Physiology, which teaches the structure and uses of the various parts of the human body, is pursued as a regular branch of study in a great number of schools; it should be in all. But physiology is in a large measure dependent upon chemistry for the explanation of its principles; and the discoveries of every succeeding year tend to make that dependence more and more complete.

Chemistry possesses also great interest from its application to the arts of daily life. It is the object of industry in acting upon the outward world to produce two classes of changes in the materials which it employs. The first are mechanical changes, which influence only the *forms* of matter, as in the operations of cabinet-making and cotton-spinning: the second are *chemical* changes, wrought in the *nature* of the substances used, and altering their properties, as in glass-making and tanning. In both these cases the changes which take place are governed by certain fixed principles or laws, to which the workman must conform if he would operate successfully.

The principles of mechanics, taught by natural philosophy, are quite generally understood; indeed, as this science considers only the relations of *masses of matter* which readily strike the senses, it was very naturally investigated earlier, and has always been a more popular study than Chemistry, which inquires only concerning the relations of *invisible atoms.* Yet the laws which control chemical action are as unchangeable as those which hold the planets in their places; every kind of matter is subject to them, and no vocation in which they are concerned can be pursued to the best advantage unless they are clearly understood. The farmer, the miner, the metalurgist, the paper-maker, the bleacher, the dyer, the druggist, the soap-manufacturer, the painter, and innumerable other craftsmen, are constantly acting upon chemical substances—constantly dealing with chemical laws—and hence, it is clear, require to know what they are. The greatest economy of process and perfection of product can only be obtained where the *principles* of a manufacture are distinctly comprehended. In such case the skilful operator is enabled to work *with* the natural laws, and not *against*, or regardless of them. It is said that in civil affairs it is always best to keep the law on our side, but in dealing with nature this is vastly more important; because when *natural laws* are violated there is no such thing as escaping the penalties.

A most instructive illustration of the effect of neglecting chemical principles, while those of mechanics are thoroughly understood and applied, is afforded by the present condition of the United States Capitol at Washington. The architectural beauty and mechanical excellence of that edifice are well known; but the freestone (sandstone) of which it is constructed was selected without due attention to its chemical and physical properties, and is totally unfit for its purpose, being rapidly acted upon and crumbled to dust by the common atmospheric agents. This destructive process has been partially arrested by the free use of paint; but the Secretary of the Interior has informed Congress that this expedient is ineffectual, and that unless scientific men come to the rescue, and invent some new preparation, which, by being applied to the stone, shall completely protect it from the action of the air, the whole structure will be reduced to a mound of sand in *one-fifth* the time that it would last if built of common marble.* It is thus seen that chemical principles are involved even in avocations most purely mechanical; so that the best reasons exist for making them objects of universal study.

Among the various occupations which require a knowledge of this science to be successfully carried on, that most noble, useful, and universal of all human pursuits, agriculture, stands prominent. The farm is a great laboratory, and all those changes in matter which it is the farmer's chief business to produce are of a chemical nature. He breaks up and pulverizes his soil with plough, harrow, and hoe, for the same reason that the practical chemist powders his minerals with pestle and mortar; namely, to expose the materials more perfectly to the action of chemical agents. The field can only be looked upon as a chemical manufactory; the air, soil, and manures are the farmer's raw materials, and the various forms of vegetation are the products of manufacture. The farmer who raises a bushel of wheat, or a hundred weight of flax, does not fabricate them out of nothing: he performs no miraculous work of creation, but it is by taking a certain definite portion of his raw material and converting it into new substances through the action of natural agents; just as those substances are again manufactured in the one case into bread, and in the other into cloth. When a crop is removed from the field, certain substances are taken away from the ground which differ with different kinds of plants; and if the farmer would know exactly what and how much his field loses by each harvest, and how in the cheapest manner that loss may be restored, Chemistry alone is capable of giving him the desired information. To determine the nature and properties of his soil, its adaptation to various plants, and the best methods of improving it; to economize his natural sources of fertility; to test the purity and value of commercial manures, and of beds of marl and muck; to mingle composts and adapt them to special crops; to improve the quality of grains and fruits; to rear and feed stock, and conduct the dairy in the best manner, farmers require a knowledge of this science. Nor can they, as a class, much longer afford to be without it; for it has always been found that the application of scientific principles to any branch of industry puts power into the hands of the intelligent to drive ignorance from the field of competition; so that as discoveries multiply, and information is diffused, those farmers who decline to inquire into the principles which govern their vocation, or who prefer the study of politics to that of agriculture, will have occasion to groan more deeply than ever over the unprofitableness of their business.

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* The United States Patent Office and Treasury Building are constructed of the same material.

As agriculture in this country has no established system of collegiate education, such as is possessed by the other professions, the rudiments of those sciences upon which it depends should be communicated to the young in common schools and academies throughout the land. It is not expected that Chemistry can be taught in a full and complete manner in ordinary schools; but very much of its general principles may and should be inculcated there, so that if higher advantages are not subsequently afforded to the pupil, he will be enabled to pursue the subject privately, in whatever application of it his business may chance to require.

There are also potent reasons why Chemistry should be embraced in a liberal system of mercantile education. The extent to which a vast variety of commercial articles are adulterated, for fraudulent purposes, and thus greatly depreciated in value, is little suspected by those unacquainted with the facts. These gross impositions upon the public cannot be arrested by penal enactments; the only effectual way of preventing them, or of sheltering the community from their effects, is for the merchant to possess himself of the necessary knowledge to determine between spurious and genuine articles.

It is eminently proper also that Chemistry should be taught to girls. In the present arrangements of society, domestic duties, either by supervision or direct performance, devolve chiefly upon females; and household operations, such as the cooking and preparation of food for the table, the preservation of fruits and meats, and the various processes of cleansing, can only be best performed when the principles of Chemistry are well understood. It is also worthy of consideration, whether substantial information upon this subject might not be beneficially substituted for much of that trivial knowledge which is imparted in fashionable female education.

But besides those more palpable benefits which spring from the application of Chemistry to daily business, there are others connected with the mind itself, which deserve to be noticed in this place. The superiority of the natural sciences over all other objects of study, to engage the attention, and awaken the interest of pupils, is conceded as a fact of experience by the ablest teachers. This cannot be otherwise; for the infinite wisdom of the Creator is nowhere so perfectly displayed, as in the wonderful adaptation which exists between the young unperverted mind, and the natural world with which it is encompassed.

On one hand there is the realm of nature, endless in the variety of its objects, indescribable in its beauty, immutable in its order, boundless in its beneficence, and ever admirable in the simplicity and harmony of its laws; on the other, there is the young intellect, whose earliest trait is curiosity, which asks numberless questions, pries into the reason of things, and seeks to find out their causes as if by the spontaneous promptings of instinct. The study of nature is therefore the most congenial employment of the opening mind, and one of its purest sources of pleasure. Every fact that is learned becomes a key to others; every progressive step discloses wonders previously unimagined. The more we acquire, the greater is our desire to learn, while each advance multiplies the sources of delight instead of exhausting them.

But the advantages of studying the natural sciences are by no means confined to the interest or enthusiasm which they are capable of exciting. They are also eminently fitted to train the mind to habits of careful observation; to teach it discrimination in deciding upon evidence, caution in forming opinions, method in study; to discipline it to patient and persevering effort, and store it with valuable knowledge. And yet, in our current systems of instruction, how frequently is the mind cut off from the glorious works of Almighty power, and directed to the crude and imperfect performances of man! how often does the bright volume of Creation, "written," to use the impressive words of Lord Bacon, "in the only language which hath gone forth to the ends of the world unaffected by the confusions of Babel," remain a sealed book, while the youthful mind is inflated with fictitious learning, or occupied in acquiring the least valuable kinds of information! It is not to be forgotten, that so long as men neglected the study of nature, despised experiment, resorted to fanciful theories for the explanation of all natural occurrences, and wasted their energies in aimless and sterile speculations, society remained in a condition of barbarism, and learning was only an empty boast, a something of which the great mass of mankind knew absolutely nothing, and which was of little service to those who possessed it. But when at length men became the students of nature, when they began to appreciate the significance of her facts, and to search for them with earnestness, then came the knowledge which put stagnant society in motion, which conferred power upon the masses to elevate and improve their condition. Then came the discovery of the New World, of the art of printing, of the telescope, the microscope, the steam-engine, the chronometer, the power-loom, the steamboat, the locomotive, the electric telegraph, the daguerreotype, and ten thousand other inventions in all the departments of human activity; and which constitute but the beginning of what yet remains to be done. The benign results which thus flow from the study of natural science, are in an eminent degree characteristic of Chemistry. Its principles are of universal import, of the utmost breadth of practical application, and are involved in all the vicissitudes of being which we daily contemplate around us. And in acquainting ourselves with them, we may not only gain a deeper and clearer insight into the wonders of existence, but we shall likewise obtain the most striking proofs of the wisdom of the Great Maker of the Universe.

that hitherto, in our hands, and exposed to all the various agencies which we can bring to bear on them, each element has yielded only one kind of matter, and no more. Future researches may show that bodies now regarded as simple are really compound. Potash was for a long time thought a simple element, but Davy decomposed it into potassium and oxygen, a metal and a gas.

9. *Analysis and Synthesis.*—Analysis consists in taking to pieces a compound body, to find of what elements it is composed. Synthesis is putting them together again to form a compound. *Qualitative* analysis ascertains the qualities or nature of the elements forming a compound. *Quantitative* analysis determines the quantities of these elements.

10. *Number of the Elements.*—In glancing at the vast diversity of natural objects, we might at first conclude that the elements which compose them are infinite in number, but this is not so. Chemists have as yet discovered but sixty-five; of these about twelve are reckoned as non-metallic bodies, and the remainder are classed as metals. Of the metals not more than one-third are in common use; the remaining two-thirds being so rare as to be seldom met with. The following table contains a list of all the elementary bodies at present known. Several of them have been but recently announced. The letters or symbols opposite each name stand for the substance in the new chemical language (51)*; and the numbers show what quantity of each element is taken when it enters into union with another (17).

* These numbers refer to sections.

What is analysis? What is synthesis? What are qualitative and quantitative analysis?

Are the elements innumerable? How many are there? How many are not metals? Of the metals, how many are in common use?

TABLE OF ELEMENTARY SUBSTANCES.*

(Those in *italics* are rare.)

NAMES OF THE ELEMENTS.	Symbols.	Atomic numbers. Hydrogen=1.
*Aluminum	Al.	13·69
Antimony (stibium)	Sb.	129·03
Aridium	Ar.	?
Arsenic	As.	75·
Barium	Ba.	68·64
Bismuth	Bi.	70·95
Boron	B.	10·90
Bromine	Br.	78·26
Cadmium	Cd.	55·74
*Calcium	Ca.	20·
*Carbon	C.	6·
Cerium	Ce.	46·
*Chlorine	Cl.	35·50
Chromium	Cr.	28·15
Cobalt	Co.	29·52
Copper (cuprum)	Cu.	?
Didymium	D.	31·66
Donarium	Do.	?
Erbium	E.	?
*Fluorine	F.	18·70
Glucinum	Gl.	26·50
Gold (aurum)	Au.	98·33
*Hydrogen	H.	1·
Ilmenium	Il.	?
Iodine	I.	126·36
Iridium	Ir.	98·68
*Iron (ferrum)	Fe.	28·
Lanthanium	La.	48·
Lead (plumbum)	Pb.	103·56
Lithium	Li.	6·43
*Magnesium	Mg.	12·67
*Manganese	Mn.	27·67
Mercury (hydrargyrum)	Hg.	100·07
Molybdenum	Mo.	47·88
Nickel	Ni.	29·57
Niobium	No.	?
Norium	Nr.	?
*Nitrogen, or Azote	N.	14·
Osmium	Os.	99·56
*Oxygen	O.	8·
Palladium	Pd.	53·27
Pelopium	Pe.	?

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* The atomic numbers are from the last edition of Graham's Chemistry, and give the latest corrections.

NAMES OF THE ELEMENTS.	Symbols.	Atomic numbers. Hydrogen=1.
*Phosphorus	P.	32·02
Platinum	Pt.	98·68
*Potassium (kalium)	K.	39·
Rhodium	R.	52·11
Ruthenium	Ru.	52·11
Selenium	Se.	39·57
*Silicon	Si.	21·35
Silver (argentum)	Ag.	108·
*Sodium (natrium)	Na.	22·97
Strontium	Sr.	43·84
*Sulphur	S.	16·
Tantalum, or *Columbium*	Ta.	92·30
Tellurium	Te.	66·14
Terbium	Tb.	?
Thorium	Th.	59·59
Tin (stannum)	Sn.	58·82
Titanium	Ti.	24·29
Tungsten (Wolfram)	W.	94·64
Uranium	U.	60·
Vanadium	V.	68·55
Yttrium	Y.	32·20
Zinc	Zn.	32·52
Zirconium	Zr.	33·62

11. *Organic and Inorganic Chemistry.*—Animals and plants grow and continue their being by means of what are called *Organs*, as leaves, roots, lungs, stomach, &c., and the products which they form are hence called *Organized* or *Organic* substances. The chemistry of plants and animals is therefore termed *Organic Chemistry.* On the contrary, minerals, water, and air are not produced by organs, do not grow; and the chemistry of these substances is therefore called *Inorganic Chemistry.* This branch of Chemistry opens to us the study of all the elements, and of the compounds which they form, *independent of the influence of life.* In pursuing Organic Chemistry, however, our studies are

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What are organized substances? What is Organic Chemistry? What is Inorganic Chemistry? How many elements does Inorganic Chemistry consider? Of how many simple bodies are organic substances composed?

limited to about sixteen elements, which compose the entire vegetable and animal kingdoms, together with all the great rocky masses which constitute the earth's crust.

12. These elements are marked by stars in the preceding table. As they embrace the most important relations of the science—physiological, dietetical, and agricultural, together with numerous arts and manufactures which derive their material from the organic world—we shall be chiefly employed with them in the following pages.

13. The names of these sixteen elementary substances form the left column of the Chart, and they are each represented by a square, colored diagram. Single squares stand for simple bodies, but when joined together they represent compounds. As a separate color is thus assigned to each element of a compound body, its exact composition is shown at a glance.*

AFFINITY, OR CHEMICAL ATTRACTION.

14. Elementary bodies possess the property of uniting to form compound bodies. The power or force by which

* Chlorine, Carbon, Sulphur, and Phosphorus are represented upon the Chart by their natural colors. Fluorine, from its supposed resemblance to oxygen in properties, has an analogous tint; Nitrogen is of the color of the air (sky-blue), of which it is the chief ingredient. Oxygen, as the sustainer of combustion, and the agent which changes the blood from a purple to a florid tint, is represented of a crimson color. The bases of the alkalies have various shades of blue, corresponding to the strength of the alkalies which they form. (The alkalies restore the blue vegetable colors discharged by acids.) Aluminum, the basis of clay, is of a clay-color. Silicon, which is said somewhat to resemble carbon, is of a dark color. Iron forms green-colored salt, and manganese those of a rose color.

What is said of the importance of the organic elements? What are their names? How are the simple bodies or elements represented upon the Chart?

What is chemical attraction or affinity? How does it differ from the attraction of gravitation and the attraction of cohesion? Do we study chemical affinity in its causes or its effects?

this union is effected, is called *chemical attraction*, or *affinity*. Chemical attraction is exerted to draw together or unite the particles of matter at insensible distances. It differs from the attraction of gravitation, which operates upon masses, and at all distances. It also differs from the attraction of cohesion, by uniting different kinds of matter; while cohesion binds together only particles of the same kind. Rain falls to the ground by the force of gravitation, the particles of iron are united by the force of cohesion, but in lime, the atoms of calcium and oxygen are held together by the force of affinity. Of the cause of this force we know nothing, and can study it only by its effects, which are to produce compounds differing totally in their properties from the elements which unite to form them.

15. Chemical combination is to be distinguished from mechanical mixture. Sand and sawdust may be intimately mixed, but they do not unite to form a new compound. So the two gases which compose the air, nitrogen and oxygen, are mixed together, but not chemically combined into one substance.

16. The simple bodies unite in pairs to form compounds, which are termed *binary*, because they contain but two different kinds of matter. The lines upon the Chart, converging from the left column to the right, represent the affinities of the elements. Thus *hydrogen* and *oxygen* have an affinity for each other, and combine, as the lines passing from them show,—*water* being the product of their union: *potassium* and *oxygen* are also seen to unite, forming potash: the lines from nitrogen and hydrogen meet at ammonia, also those from *oxygen* and *sodium* at *soda*. Compounds formed by

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What is the difference between *chemical* and mechanical combination?

How is affinity represented upon the Chart? What does the structure of the lines represent?

the union of plain lines are solids; of broken lines, liquids; of dotted lines, gases.

LAWS OF AFFINITY.

17. *Definite Proportions.*—Affinity is governed by several highly interesting laws, which constitute the groundwork of modern Chemistry. It is a law of affinity, that all chemical combination takes place in definite, unchangeable proportions of quantity. The gases which form water unite in the proportion of 8 to 1, by weight: 8 ounces of oxygen unite with 1 of hydrogen to form 9 ounces of water. One ounce of hydrogen will not combine with 6, 7, 10, or 12 of oxygen. Eight to one are the proportions for pure water, at all places and seasons; nor is it possible to produce it from any other proportion of its elements. Eight parts of oxygen unite with thirty-nine of potassium to form potash, with twenty-three of sodium to form soda, with twenty of calcium to form lime, and with twenty-eight of iron to form protoxide of iron. Analysis never discovers any other proportions in these compounds.

18. This law of definite proportions governs the formation of all chemical substances whatever; it is universal. All stones and minerals, the dirt of which soil consists, every vegetable product, and all parts of animal structures, consist of elements which are united in definite, unalterable proportions.

19. *Combining Numbers.*—These combining quantities, being fixed, may be expressed by permanent numbers, which are hence called *combining* numbers. Relatively, these numbers are always the same, although they are written differently upon different scales. Hydrogen, as is evident upon

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Do chemical substances combine in all proportions? What is said of the elements of water? of potash? of soda? of lime? of protoxide of iron?

What is said of the extent of this law?

What are combining numbers? Are they always the same?

the Chart, combines in the smallest proportion by weight of any known body, and is adopted as the unit upon the scale generally used. Hydrogen being assumed as 1, oxygen is 8, sulphur 16, carbon 6, and so on; but if oxygen were taken as 1, the whole scale would have to be divided by eight; or oxygen at 100 multiplies the scale by 12·5.

20. This great law of Chemistry is exhibited upon the Chart in the clearest manner. The sizes or areas of the colored diagrams correspond to the combining numbers, and thus represent relative quantities to the eye. The hydrogen square being the smallest, the oxygen square is 8 times larger, the sulphur square 16, the carbon square 6, and the chlorine square 35 times larger. Observe that diagrams of the same color have exactly the same size throughout the Chart. This could not be otherwise, as the combining proportions are always the same. Thus, oxygen, wherever found, whether in an acid or an alkali, a mineral or a vegetable substance, is seen obeying the law of its fixed proportion; its square is always of the same size; and so with all the other elements. This great law of Chemistry, so admirably illustrated by these diagrams, gives remarkable simplicity to the science; enabling the mind both to comprehend and to retain its facts with readiness and ease.

21. *Multiple Proportions.*—When combination occurs between two elements in more proportions than one, the larger quantities are multiples of the smaller by a whole number. Thus carbon and oxygen form two different compounds, carbonic oxide and carbonic acid. In carbonic oxide, as the

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By what method is this great law of definite proportions exhibited upon the Chart? Why are diagrams of the same color always of the same size? What is the effect of this law upon the acquisition of the science?

When the same elements form two or more different compounds, in what proportions do they unite? Give examples. What is said of the nitrogen and oxygen group? What is this law called?

Chart shows, oxygen exists in but one proportion; in carbonic acid the quantity is doubled. In the nitrogen and oxygen group, we see a series of five compounds, which differ essentially from each other in their properties. The amount of nitrogen is constant, but the quantity of oxygen varies as the numbers 8, 16, 24, 32, 40—a simple numerical ratio. This is called the law of *multiple proportions.*

22. When two bodies unite with each other chemically, the proportions which are taken satisfy their mutual affinities, and the quantities are therefore said to be equivalent to each other. Thus the affinity of one grain of hydrogen is exactly equal or equivalent to that of eight grains of oxygen, or thirty-five grains of chlorine. Combining numbers are hence sometimes called equivalent numbers, equivalent proportions, or equivalents; they are also termed combining weights, atomic weights, combining proportions, &c. The atomic numbers should always be associated in the mind with the names to which they are attached, because to the chemist no such thing as abstract hydrogen, oxygen, or carbon exists. It is of their atoms that he invariably speaks. The word hydrogen signifies an atom which weighs 1, the word carbon an atom which weighs 6, and the word oxygen an atom which weighs 8.

23. The law of definite proportions extends to the union of compounds, as well as of elements. The combining proportion of a compound body is the sum of the combining numbers of its several elements. The combining number for lime is calcium 20, oxygen 8=28: for water it is oxygen 8,

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What are chemical equivalents? What are combining numbers sometimes called? Why should the atomic numbers be always associated with the names to which they are attached? What does the chemist understand by the words hydrogen, carbon, oxygen?

How do we learn the combining proportions of a compound body? How does it appear that 37 is the number for hydrate of lime?

hydrogen 1=9. When water and newly burned lime unite, as in the process of slaking, the quantities are therefore 9 of water to 28 of lime, giving 37 for hydrate of lime: thus each acid and alkali has its fixed equivalent number. It is important that the combining numbers of the elements upon the Chart should be learned and remembered; the pupil should then be required to compute the numbers for the compounds which they form. Fractions have been omitted, whole numbers being more easily retained in the memory.

24. The term *gas* is applied to bodies which are neither solid nor liquid, but resemble air. Gases unite in definite proportions by *bulk* or *volume*, as well as by weight. Thus water is formed by one volume or measure of oxygen to two of hydrogen, and like simple proportions govern all gaseous combinations. But as weighing is the grand process by which all the important laws and facts of Chemistry have been established, and as the whole language and nomenclature of the science, as recognized by all chemists, has been conformed to results by weight, these alone are represented upon the Chart. Says Prof. Liebig, "The great distinction between the manner of proceeding in Chemistry and Natural Philosophy is, that one *weighs*, while the other *measures*. The natural philosopher has applied his measures to nature for many centuries, but only for fifty years have we attempted to advance our philosophy by weighing. For all great discoveries Chemistry is indebted to the balance, that incomparable instrument which gives permanence to every observation, dispels all ambiguity, establishes truth, detects error, and guides in the true path of inductive science."

What is a gas? How do gases combine? Why does not the Chart represent combination by volume? What is said of the great distinction between Natural Philosophy and Chemistry?

CAUSES WHICH CONTROL AFFINITY.

25. *Bodies combine with unequal degrees of power.*—Chemical attraction acts among different substances with different degrees of force. Thus carbonic acid will combine with soda, forming carbonate of soda; but if vinegar be brought in contact with this compound, it will drive off the carbonic acid, and take its place, forming acetate of soda. Again, the affinity of hydrochloric acid for the soda is superior to that of the acetic acid; it will therefore expel it, and form a new substance. Nitric acid serves hydrochloric in the same way, and it is in turn treated in a similar manner by sulphuric acid. It has been attempted to construct tables representing the order of affinities among different substances; but so many causes disturb the play of this force, that such tables are of little value.

26. *Relation of Heat to Affinity.*—Heat is the great antagonist of affinity. As this force draws the particles of matter together, heat tends to drive them asunder. By thus separating the atoms, and removing them beyond the sphere of each other's attraction, it weakens and overcomes chemical union. But when the affinities which bind together a compound have been destroyed by the application of a given degree of heat, other affinities of a stronger kind are brought into action, and the elements arrange themselves into new combinations. Thus, heat destroys all organic substances, but at the same time other compounds are formed, which

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Is the force of chemical attraction equal among all substances? How does vinegar affect carbonate of soda? Why does hydrochloric acid destroy this compound? What acid expels the hydrochloric? What the nitric? Why are tables showing the order of affinities of little value?

How does heat overcome chemical union? When heat destroys the affinities of a compound, what follows?

resist the decomposing power of combustion. Heat, by melting solid substances, and thus bringing them into a state of liquidity (29), also calls new affinities into exercise, as in glass-making (296, 303).

27. *Influence of Light.*—Light exerts a powerful agency in modifying affinity. Hydrogen and chlorine gases mingled together in the dark do not unite; but if brought into the sunshine they combine explosively. The daguerreotype process depends upon the chemical action of light, exerted upon metallic plates coated with various substances. Light is also the great agent which controls the growth of vegetation, as all vegetable fabrics are built up under its direct influence (329).

28. *Effect of Electricity.*—Affinity is also controlled by electricity, which by many is supposed to be the basis of all chemical action. Atoms which are attracted together are assumed to be in different electrical states, as opposite electricities are known to attract each other. If two slips of different metals have their lower ends dipped into an acid, corrosion (chemical action) immediately takes place; and if their upper ends are connected, either by being inclined together or by a third slip of metal, an electrical current is created. This is called a simple voltaic circuit, and involves the principle of the galvanic battery. Electrical currents are among the most powerful means of producing chemical decomposition.

29. *Cohesion.*—As affinity only takes place among particles of different kinds of matter at insensible distances (14),

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What is said of the effect of light upon affinity? Upon what does the daguerreotype process depend? How does light influence vegetation?

How is electricity supposed to act in controlling chemical action? In the voltaic circuit and galvanic battery, to what is the electrical current due?

Why is cohesion opposed to chemical action? How is cohesion best overcome?

cohesion, which holds together atoms of the same kind in masses, must be opposed to chemical action. Substances when in the solid state, even if ground to a fine powder and mixed, very rarely combine chemically. To afford full scope for affinity, cohesion must be completely overcome; and this is best done by melting or dissolving the bodies in a liquid, that their particles may be brought into the most intimate contact.

30. *Effect of the Nascent State.*—Elements at the very moment they are liberated from union, in what is called the growing or nascent state, often enter into new combinations which cannot be formed under other circumstances. Nitrogen and hydrogen, if mingled in the same vessel, do not unite; but when these two gases are set free at the same time, by the decomposition of vegetable matter, they readily combine to form ammonia.

31. *Catalysis.*—Chemical union is also sometimes influenced in a peculiar manner by what is called *presence-action*, or *contact-action*, or *catalysis*. In this case, a body, by its presence or contact, *induces* changes in another, in which it takes no part. Thus if starch is boiled in a little weak sulphuric acid, it is converted into sugar; and if at the termination of the process the acid be examined, it will be found to remain unaltered, both in properties and quantity; so that the smallest proportion of the acid is sufficient to convert into sugar an indefinitely large quantity of starch. The phenomena of catalysis are not well understood.

What is said of the combination of elements just liberated from union? Give an example.

What is the mode of action of catalysis? Are the phenomena well understood?

THE ATOMIC THEORY.

32. It has been proposed to explain the laws of chemical combination by what is called the *atomic theory.* This theory assumes, first, that the ultimate particles or molecules of which all matter is composed are indivisible, unchangeable atoms; second, that atoms of the same element are uniform in weight, but that in different elements they have different weights; third, that the combining numbers represent these relative weights; and fourth, that chemical compounds are formed by the union of these atoms with each other. When these propositions are admitted, the known laws of combination follow necessarily. If bodies unite by atoms, atom to atom, their proportions must be *definite,* and always the same. If several similar atoms unite, as each is indivisible, they must be *multiples* of each other (*multiple proportions*); and as one atom may replace another in a compound, their relation must be that of *equivalents.* This theory has been so universally received by chemists, that its terms have become incorporated with the language of the science; so that to say an atom of iron combines with an atom of oxygen, is as common as to say that a proportion or equivalent of iron combines with an equivalent proportion of oxygen.

33. Of the form or figure of atoms nothing whatever is known. It is therefore no matter in what shape they are represented, as the object is not to indicate their *figure,* but their relations.

34. If each square upon the Chart is considered to represent

Upon what assumed grounds is the atomic theory based? Do the laws of combination result from these propositions? What is said of the reception of this theory by chemists?

Is any thing known of the form of atoms?

How does the Chart give a clear idea of the atomic theory?

an atom, we shall then have a clear view of the atomic theory. Single atoms are seen to combine to form compound atoms: thus an atom of water contains two elementary atoms, of silica four, and an atom of gluten eighty-four simple atoms. Until the announcement of the atomic theory, we had no adequate explanation of the uniformity of the proportions of chemical combination, or of the nature of the cause which renders combination in other proportions impossible.

35. *Crystallization.*—When certain solid substances are dissolved in liquids or melted, so that their particles are free to move among each other, upon the evaporation of the liquid, or the cooling of the melted mass, the atoms arrange themselves together in certain regular geometrical forms, called *crystals.* The process by which crystals are formed is called *crystallization.* Thus, when common salt crystallizes, its atoms arrange themselves in the form of dice or cubes. Alum assumes the form of a double pyramid placed base to base.

36. Attraction, in causing atoms to cohere so as to form solid masses, seems not to act equally all around each atom, but between certain sides or parts of one atom, and corresponding parts of another; so that when allowed to unite according to their natural tendencies, they always assume a certain definite arrangement. This property of atoms has been called their *polarity,* because in these circumstances they seem to resemble magnets, which attract each other only by their poles. When the arrangement of its atoms is not crystalline, a body is said to be *amorphous.* Any change which tends to permit freedom of motion among the atoms of amorphous bodies, favors the reaction of the polar forces, and promotes crystallization.

What are crystals? What is crystallization? What form do the crystals of common salt assume? What those of alum?

What is said of the polarity of atoms? In this property, what do they resemble? What is an amorphous body?

37. The power with which atoms arrange themselves in the crystalline order is seen in the freezing of water; as the particles assume their new position, the water expands with a force sufficient to burst the strongest iron vessels, or to rend solid rocks.

38. Blows, continued vibration, friction, and variations of temperature produce changes in the molecular arrangement of metals; and it is thought that the axles of railroad-cars, though at first constructed of tough and fibrous wrought-iron, may from these causes acquire that crystalline and brittle structure which they often exhibit upon breaking. Crystals of the salts often contain water, called the water of crystallization. These, when exposed to the air or to heat, part with this water, lose their transparency, turn white, and fall to powder: this is called *efflorescence.* Others attract water from the air, and this is known as *deliquescence.*

39. The primitive geometrical forms which crystals assume are divided into six classes or systems, and in each of these classes there is a vast number of secondary forms. Thus in carbonate of lime, 680 modifications of crystalline form have been described. As the subject of crystalline forms, to be made interesting, requires full details, we must refer the inquiring student to the complete treatises upon Mineralogy and Crystalography.

40. When the same body possesses the property of being crystallized in two different systems, it is said to be *dimorphous. Isomorphous* bodies are such as have the property

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What is said of the force with which atoms arrange themselves in the crystalline form? Give an example.

What is said of the effect of blows, friction, and vibration of the axles of rail-cars? What is efflorescence? What is deliquescence?

How many primitive geometrical forms do crystals possess? How many secondary forms of carbonate of lime have been enumerated?

What is a dimorphous body? What are isomorphous bodies?

of replacing each other in crystals without giving rise to new figures. Ten groups of isomorphous bodies have been discovered.

41. *Isomeric compounds* are such as contain the same elements, in the same proportions, and yet have different properties. Formerly it was supposed that compounds having the same chemical constitution must necessarily have the same qualities, but such is now proved not to be the fact. Spirits of turpentine, the oil of lemons, oil of juniper, oil of black pepper, and oil of bergamot, as is seen from the Chart, contain equal amounts of carbon and hydrogen, yet their properties are very different. Oil of roses and illuminating gas are also identical in composition. The difference of properties in isomeric bodies is accounted for by supposing that the atoms or molecules are differently arranged in the different cases, as is represented in the Chart.

42. *Allotropism.*—Chemists have lately shown that many of the elements may exist under two or more different conditions, called *allotropic states*. In one state they readily exert their usual active properties; in the other they seem passive, and as it were torpid. Thus the diamond is the passive form of carbon, and it can hardly be made to burn in oxygen gas; while lamp-black, which is one of its active forms, is so highly combustible that it often takes fire spontaneously in the open air. It has been suggested that these conditions of the elements are retained when they enter into combination.

What are isomeric compounds? Give examples. How is the difference of properties in these compounds accounted for?

What are allotropic states? What examples are offered?

THE NOMENCLATURE.

43. The chemical nomenclature is a system of naming, in which the structure of the terms employed expresses the composition of the substances to which they are applied. This nomenclature is the most perfect to be found in any of the sciences. It is very simple, and gives the mind great power over the subject.

44. In the case of simple bodies, the rule is to retain the old established terms; but when a new element is discovered, to give it a name expressive of some leading property. Thus, chlorine takes its name from its greenish color, and iodine from its purple vapor. All the lately discovered metals are distinguished by a common termination, as potassium, sodium, platinum, &c.

45. Compound bodies are of three kinds, *acids*, *bases*, and *neutral* bodies, or those which possess neither acid nor basic properties. Acids are usually known by the following properties: a sour taste, a power of altering vegetable colors (changing blues to red), and the property of combining with and neutralizing or destroying the properties of the bases or alkalies.

46. A large number of the acids are formed by the union of oxygen with other bodies; they are then named from the element with which the oxygen unites. Thus, sulphur with oxygen gives sulphuric acid, carbon with oxygen gives carbonic acid, phosphorus with oxygen forms phosphoric acid. Acids in which there is no oxygen are named from both their

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What is the chemical nomenclature? What is said of it?

What is the rule in the case of simple bodies? Give examples.

How are compound bodies divided? What are acids?

How are a large number of the acids formed? How are these named? Give examples. How are acids named which contain no oxygen? When the same elements: thus, hydrogen and chlorine form hydrochloric acid, hydrogen and fluorine hydrofluoric acid. When different acids are formed by the union of the same elements in different proportions, they are distinguished by terminations and prefixes. The termination *ic* describes the strongest, *ous* a weaker, and the prefix *hypo*, which means under, a still weaker acid. Thus nitr*ic* acid contains a higher proportion of oxygen than nitr*ous* acid, and this more than *hypo*nitrous acid (see Chart). The prefix *hyper* means more, as *hyper*-chloric acid, or more commonly *per*chloric, which contains more oxygen than chloric acid.

47. *Bases* are distinguished by their power of combining with and neutralizing acids. They include the alkalies, which have a peculiar acrid taste, as lime, called the alkaline taste; and have also the power of restoring vegetable blues when destroyed by an acid. Besides the alkalies, bases also comprehend those metallic oxides which do not exhibit these alkaline properties, but yet unite with acids.

48. Most of the bases are formed by the union of oxygen with another element, commonly a metal; as oxygen with iron, termed oxide of iron, oxygen with potassium, oxide of potassium, &c. When oxygen combines with the same element in different proportions, forming several oxides, its quantity is indicated by the use of prefixes. Thus *proto* indicates one equivalent or the lowest proportion of oxygen; *deuto*, two, and *trito*, three, equivalents of oxygen. *Per* is used to express the highest degree of oxidation, and is often applied

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elements form different acids, how are they distinguished? What is the meaning of *ic*, of *ous*, of *hypo*, of *hyper*, or *per*?

How are bases distinguished? What bodies are comprehended by the term bases?

How are most of the bases formed? How is the quantity of oxygen in an oxide denoted? What does *proto* indicate? *Deuto*? *Trito*? How is *per* used? What are *suboxides*? What are *sesquioxides*?

as the deutoxide and tritoxide. Some oxides, which have such inferior basic properties as not to combine with acids, are termed *suboxides*. Binoxide is equivalent to deutoxide; and *sesquioxides* are those in which the oxygen is in the proportion of one and a half to one of the element with which it is combined. (See Chart, Binary Compounds.)

49. The acids and alkalies, although possessing opposite properties, have a powerful attraction for each other, and combine to form salts. By this union the properties of both the acids and bases are completely lost, and a neutral salt is the result. If, however, there is not sufficient base completely to saturate the acid, an *acid*-salt, or *super*-salt, results; while if the base is in excess, a *basic*-salt, or *sub*-salt, is formed. Salts are named after both their elements, as phosphate of lime, from phosphoric acid and lime. But as several acids of the same general name may combine with one base, the salts are distinguished by turning the *ic* of the acid into *ate* of the salt, and *ous* into *ite*: thus nitric acid forms nitrates, nitrous acid nitrites, and hyposulphurous acid hyposulphites. The basic element of a salt is indicated by its usual prefixes; thus, protosulphate of iron is a sulphate of the protoxide of iron. (See Chart.) Salts formed from elements containing oxygen are termed oxygen-acid salts: those containing no oxygen are named *haloid* salts, from their resemblance to sea-salt—chloride of sodium (291).

50. As oxygen forms oxides, so chlorine forms chlorides, bromine bromides, iodine iodides, fluorine fluorides, sulphur sulphides, phosphorus phosphides, and carbon carbides. The

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When acids and alkalies unite, what is the result? What is a *super-salt*? What a *sub-salt*? How are salts named? Example? When several acids of the same general name combine with one base, how are the salts distinguished? Examples? How is the degree of oxidation of the base of a salt represented? What are oxygen-acid salts? What are haloid salts?

To what compounds are *ide* and *uret* attached?

compounds of these last three substances are known most generally by the termination *uret*, as sulphuret of iron, carburetted hydrogen.

51. *Chemical Symbols.*—In the case of most organic compounds the nomenclature fails, and cannot be made to express composition. Another expedient has been happily resorted to, which meets the difficulty: it is the use of what are known as chemical symbols. For the symbol of an elementary substance we take the first letter of its name; but as several substances may have the same initial letter, to distinguish between them, we either employ the first letter of their Latin names, or add a *second* small letter. Thus, C stands for carbon, Cl for chlorine; and as P is taken for phosphorus, K, from *kalium*, the Latin for potash, is taken for potassium. A symbolic letter represents not only an element, but *one atom* or *proportion of that element*. Thus, N O stands for one atom of nitrogen and one of oxygen, which forms nitrous oxide. If more proportions than one are to be expressed, a small figure is added in the same manner as the powers of roots are expressed arithmetically by exponents. Thus, $N\,O_5$, represents nitric acid, which contains five equivalents of oxygen. A large figure placed before a parenthesis indicates that all included within it is to be multiplied; thus, $3(S\,O_3 + H\,O)$ represents three atoms of hydrated sulphuric acid. Some writers dispense with the parenthesis. A collection of symbols is called a *formula*.

52. *Equations and Diagrams.*—Chemical changes are shown by means of formulæ arranged in the manner of an equation. The separation of carbonic acid, and the formation

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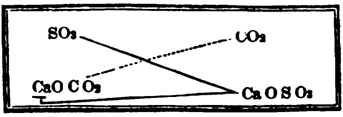
What takes the place of the nomenclature in Organic Chemistry? What is taken as the symbol of an element? When two elements have the same initial letter, how do we distinguish between them? Give some examples. How is the proportion of an element expressed? Examples. What are formulæ?

of plaster of Paris, when sulphuric is added to carbonate of lime, is thus represented: $Ca\,O \; C\,O_2 + S\,O_3 = Ca\,O \; S\,O_3 + C\,O_2$. The substances to be changed, carbonate of lime and sulphuric acid, are placed at the left; the products of the change, sulphate of lime and free carbonic acid, are seen at the right. A still better way of illustrating decomposition is by means of lines, such as are shown upon the Chart. By this method the foregoing changes appear as in the above diagram. Here the substances to be changed and the products of change are not only arranged opposite each other, as in the equation, but the character of the change is exhibited more clearly. The plain lines show that one of the products is a solid, and the dotted line that the other escapes as a gas (16). As there is nothing lost during the change, the equivalents upon each side, if added together, will produce equal amounts.



53. It is very important that the nomenclature and the use of symbols should be well learned; and as the common way of teaching this part of the subject is difficult, tedious, and unattractive, it is desirable that beginners should have the Chart constantly before them while attending to it. Much time and labor will thus be saved, while clear, and therefore the most lasting ideas are acquired.

MANIPULATION, OR THE OPERATIONS OF CHEMISTRY.

54. Manipulation means hand-work: it is a term applied to all the practical operations of Chemistry. To become an

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How are chemical changes shown? How are the substances arranged? What is said to be a still better way of illustrating chemical changes?
What is chemical manipulation?

expert manipulator requires great experience, tact, and a high perfection of bodily senses; but many useful operations may be executed with but slight practice and few instruments. The object of all chemical investigation is to ascertain something unknown in reference to the properties of bodies, and this is done in various ways.

55. We determine by taste if bodies are sweet, like sugar; sour, like vinegar; bitter, as epsom salts; saline, as common salt; burning, as alcohol; insipid, as water which has just been boiled, or entirely tasteless. The properties of many substances are revealed by the odors they emit. Thus the peculiar smell of burnt feathers, woollen rags, &c., indicate animal substances. Color is an important property of bodies, and should always be noticed. Some experience is necessary to identify different shades from description; and the pupil will do well to procure slips of paper of a large variety of tints, and paste them in a book with the name of the color opposite each.

56. The property of hardness, which is very important in reference to minerals, is determined in a comparative way, by rubbing or rasping one body against another, and observing which is scratched. Thus talc is scratched by gypsum, and gypsum by calcareous spar. The diamond scratches all bodies and is itself scratched by none. The finger nail also affords a good indication in this way; soapstone and plaster of Paris yield readily to it, while limestone is but slightly affected.

57. Weight is a fundamental property of all bodies; to ascertain it accurately is therefore a matter of great impor-

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How are the properties of many bodies easily determined? What is said of color?

How do we ascertain the comparative hardness of bodies?

What is said of weight? How is weighing performed?

tance. When we take a piece of wood in one hand, and a piece of lead of the same size in the other, we say that one is heavy and the other light. We mean that they are heavy and light compared one with the other; these terms, then, always express the comparative weight of *equal bulks* of different substances. We have standards or units of weight with which all bodies may be compared, as troy weight, apothecaries' weight, &c. Weighing is performed by means of an instrument called the balance or scales. No balance should be used, even for the roughest chemical work, that will not turn with the tenth of a grain.

58. *Specific Gravity.*—The specific gravity of a body is its weight compared with either water or air. Solids and liquids are usually compared with distilled water, gases with common air. A cubic foot of water weighs about 1000 ounces; a cubic foot of iron weighs 7800 ounces; it is therefore 7 and $\frac{8}{10}$ times heavier than water, hence we say its specific gravity is 7·8. Gold is 19½ times heavier than water; its specific gravity is 19·5. The specific gravity of a solid is obtained by first weighing the body out of the water, and then weighing it suspended in the water, when it will be found to weigh less. The weight in air is divided by the loss in water, and the quotient gives the specific gravity of the substance. The specific gravity of a liquid may be obtained by filling with it a bottle which will hold just 1000 grains of pure water, and then weighing it. Such a bottle will hold just 1340 grains of molasses, 1840 grains of oil of vitriol, 13,500 grains of quicksilver, and only 840 grains of alcohol: these numbers, divided by 1000, give the specific gravities of these several substances.

What is meant by the specific gravity of a body? What are solids and liquids compared with? Gases? How do we determine the specific gravity of a solid? How of a liquid?

59. Pulverization, trituration, or comminution, is the breaking or grinding down of hard substances into powder. It is effected usually in a strong vessel termed a mortar, made of Wedgwood's ware, or porcelain, Fig. 1. This operation must be performed upon most solid bodies before they can be dissolved.

Fig. 1.

60. *Solution.*—The act of dissolving, by which a solid substance, when placed in a liquid, disappears, leaving the liquid clear, as sugar or common salt in water. A gas may also be said to dissolve in a liquid when it is absorbed by it. The liquid which effects solution is called the solvent. *Infusion* and *digestion* consist in steeping or soaking substances in liquids in order to dissolve some portion of them.

61. *Precipitation* consists in the separation of a dissolved substance from the liquid solvent. Spirits of camphor is a solution of camphor in alcohol. If water be added to it, the camphor separates from the alcohol as a white cloud, which soon settles to the bottom: it is precipitated. The substance separated from the solution is called the precipitate, the substance added the precipitant.

62. *Filtering.*—The act of straining, by which solid substances (usually precipitates) are separated from liquids. Coarse sand or cloth is sometimes used to form a filter, but most commonly porous or unsized paper (filtering paper). The paper is cut into pieces of a circular form, Fig. 2, and folded over, as the cross lines represent. It then readily assumes the form Fig. 3, when it is placed within a funnel

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How is trituration performed?

What is meant by solution? What by infusion and digestion?

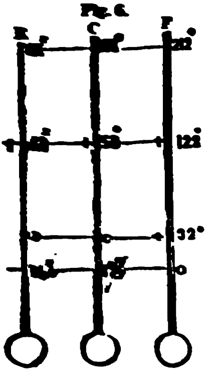
What is precipitation? Give an example. Which is the precipitate? Which the precipitant?

What is filtering? What substances are used as filters?

melting, the position of the mercury is marked, and called the freezing point, or more properly the point of melting ice. The tube is then plunged into boiling water, the mercury expands, and the height to which it rises is marked as the boiling point.

56. In the centigrade thermometer, which is used in France, the space upon the scale that intervenes between the freezing and boiling points is marked into 100 equal divisions, called degrees. The zero, or cipher from which we begin to count, is therefore the freezing point, and 100° the boiling point. This is the most natural and perfect scale. Reaumur's thermometer, used in the north of Europe, has the same space upon the scale divided into 80°, and Fahrenheit's thermometer, the one used in this country and England, has the same portion of the scale divided into 180°; but what is very singular, it has the zero, or point at which we commence reckoning, fixed at 32° below the freezing point, so that from zero to the boiling point we have 180° + 32° = 212°. The centigrade thermometer is represented by the letter (C), Reaumur's by (R), and Fahrenheit's by (F). The degrees above zero are marked with the sign (+), those below with the sign (−); see Fig. 6.

Fig. 6.



The following table exhibits several interesting facts in regard to temperature:

How are the spaces between these two points divided in different thermometers? Which is the most natural scale? How are degrees above and below the zero point distinguished?

Greatest artificial cold measured (Faraday)	−166° F.
Greatest natural cold observed by a "verified" thermometer (Sabine)	56°
Estimated temperature of the planetary spaces (Fourier)	58°
Mercury (quicksilver) freezes	39°
A mixture of equal parts of alcohol and water freezes	7°
Ice melts	+ 32°
Greatest density of water	39·8°
Mean temperature at the equator	81·5°
Heat of human blood	98°
Highest natural temperature observed (of a hot wind in Upper Egypt.—Burkhardt)	117·8°
Alcohol boils	172·94°
Water boils	212°
Tin melts	442°
Lead melts	612°
Mercury boils	660°
Red heat (Daniel)	980°
Heat of a common fire (Daniel)	1141°
Brass melts	1869°
Silver melts	2233°
Cast-iron melts	3479°

68. Thermometers should never be suddenly plunged into very cold or very hot water, as the glass is liable to crack; and the indications of thermometers bought at the shops or instrument-makers ought not to be trusted, unless they are at first carefully compared with some well-known standard instrument. The mercurial thermometer is capable of measuring accurately only about 600 degrees of heat; temperatures higher than this are shown by instruments called pyrometers, which operate by the expansion and contraction of solid bodies.

What precautions should be observed in using thermometers? In buying them? What is the limit of the indications of the mercurial thermometer? How are higher temperatures measured?

OF THE CHEMICAL ELEMENTS, AND THEIR COMPOUNDS.

OXYGEN.

Symbol O, *equivalent* 8.

69. THIS is the most important of the elements. It is in some way concerned in nearly all chemical changes, and in most of them it takes a very prominent share. As we shall be much in its company in the following pages, it will be well to make its acquaintance first.

70. *Properties.*—The condition of oxygen is that of a gas; that is, it resembles common air, which is a mixture of several gases. Some gases when exposed to great cold are brought down to the liquid, and even the solid state (168), and others are condensed into liquids by pressure: but no degree of cold or pressure ever yet applied has been able to overcome or destroy the gaseous properties of oxygen; chemical force alone can do this. Oxygen is transparent, colorless, tasteless, and inodorous, like common air; it is about one-tenth heavier than that body, and possesses the same mechanical properties. It acts neither as an acid nor an alkali, and is dissolved sparingly by water, 100 gallons absorbing about 4½ of the gas. The term oxygen signifies acid-former. It was applied by Lavoisier, who supposed it to be the active principle of all acids, an opinion now known to be false. There is reason to believe that oxygen is capable of existing in two allotropic states (42), a passive or quiescent state, and an active condition, in which its affinities are

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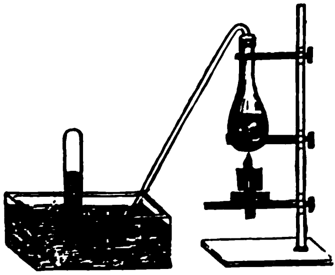
What is said of oxygen?

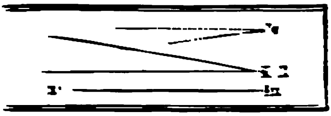
In what state does oxygen exist? What force alone can change it into a liquid or solid condition? What are its properties? What is the meaning of the term oxygen? Why was it so named? What is ozone?

greatly exalted. The *ozone*, discovered in the atmosphere by Prof. Schonbein, concerning which much has been said, is supposed to be the active form of oxygen.

71. *Preparation.*—We prepare the purest oxygen, and in the readiest way, from chlorate of potash. A portion of this salt is powdered, dried, and mixed with about one-fourth its weight of black oxide of manganese, or oxide of copper, and heated in a flask, retort, or tube, over a spirit-lamp. The gas comes off copiously, and is collected in jars over water. The pneumatic trough, which is used for this purpose, may be any convenient vessel, containing a shelf, and holding sufficient water readily to fill a jar placed within it, which is then inverted and put upon the shelf. The water in the trough must cover the mouth of the jar. The gas is delivered by the tube at the open end of the jar, through which it rises, displacing the water, and gradually filling the vessel. This arrangement is shown in Fig. 7. The oxide of manganese or copper is not in any way changed; it acts by catalysis (31), promoting in a very high degree the decomposition of the chlorate. Chlorate of potash costs about one dollar per pound, and one ounce will yield about two gallons of the gas. Oxygen may also be prepared by exposing a mixture of bichromate of potash and sulphuric acid, or peroxide of manganese and



How is pure oxygen gas best obtained? What is a pneumatic trough? How is the oxygen collected? How does the manganese act in promoting decomposition?



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with other substances. So vehement is this action that fire is produced, and hence oxygen is the great supporter of combustion. All substances which burn in the air, burn in pure oxygen gas with greatly increased brilliancy. An extinguished candle plunged into it is instantly relighted if the least spark of fire remain upon the wick. Iron wire burns in it with vivid scintillations, and phosphorus with a light so brilliant that the eyes cannot endure it. In all these cases the light and heat are produced by the chemical union of the oxygen with the burning body, the weight of which is increased exactly in proportion to the amount of oxygen consumed. All the common cases of combustion which take place in the air are due to the same cause—the combination of its oxygen with combustible substances. It here proceeds in a more subdued and regulated way, because atmospheric oxygen is diluted with four times its bulk of another gas, which if taken alone extinguishes fire altogether.

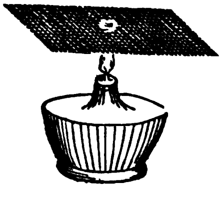
75. *Illumination.*—Two conditions are necessary for illumination: a sufficiently high temperature, and the presence of solid matter within the heated space. Neither of these conditions alone answers the purpose. The burning of pure oxygen and hydrogen gases together produces intense heat, but is without sufficient light to be even visible in the daytime; and a fire of charcoal which contains no gas, also yields very little light. But if solid carbon be placed within the oxy-hydrogen flame, a brilliant illumination at once ensues. The elements of oil, tallow, wood, &c., with which oxygen unites in ordinary burning are chiefly hydrogen and carbon; the hydrogen it burns to water (90), and the carbon to carbonic acid (167), both escaping away into the atmosphere.

What two conditions are essential for illumination? What is said of the burning of hydrogen and charcoal? How can the oxy-hydrogen flame be made to give a brilliant light? In the ordinary burning of oil, &c., what takes place?

76. The affinity of oxygen for hydrogen is superior to its affinity for carbon. It therefore seizes upon the hydrogen first, where it is present in sufficient quantity, burning it with the production of intense heat. The solid carbon is at the same time set free, and its particles being heated to a luminous whiteness, produce the light which is emitted from the flame. The luminous particles of carbon, floating forward as they are liberated to the surface of the flame, come in contact with atmospheric oxygen, and are there consumed. When the burning body contains both elements, but a disproportionate amount of carbon, as in spirits of turpentine, more of it is set free than can be consumed by the oxygen, and the flame smokes. When the hydrogen is in excess, as with alcohol, there is much heat, but little light, and no smoke; when mingled, these liquids correct each other's defects, and form the basis of "burning mixtures."

77. *Structure of Flame.*—Common flame is not, as it appears, a solid cone of fire, but a hollow luminous shell, as is shown by holding a piece of metallic wire gauze over the flame of a common lamp, Fig. 8. In the centre there appears a dark space, surrounded by a ring of light. This dark central portion is constantly filled with gases, formed from the tallow or oil by heat, in precisely the same manner that they are distilled from coal and resin by the gas-manufacturer. The inclosed gases generated at *b*, Fig. 9, cannot, of course, be burned up until they pass to the surface of

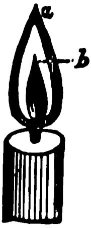
Fig. 8.



Why is the hydrogen burned first? What produces the light? When will flame smoke? When will the light be deficient? How are burning mixtures formed?

How is common flame shown to be hollow? What is contained in this hollow space? What is said of the argand lamp? Why is the flame pointed?

Fig. a



the flame at *a*, for want of oxygen. In argand lamps the wick is circular and hollow, and a stream of air is admitted to the interior of the flame, which thus has a double burning surface. A tall glass chimney is placed over the flame, which secures a strong upward current, and hence an abundant supply of oxygen to the flame. · The conical or pointed form of the flame is caused by the rising currents of heated air.

78. Despritz has shown that the heat evolved in all common cases of combustion, depends upon the quantity of oxygen consumed, and not upon the amount of the combustible with which it unites. Thus a pound of oxygen combining with hydrogen, charcoal, and alcohol, gives in each case very nearly the same quantity of heat; each raising 29 pounds of water from the freezing to the boiling point. The amount of heat produced by equal weights of different combustibles, combining with oxygen, he found to be as follows:

1 pound of	charcoal . .	raised from	32° to 212°,	78	lbs. of water.
"	wood holding 20 pr. ct. of water	"	"	27	"
"	alcohol	"	"	68	"
"	oil or wax	"	"	90	"
"	hydrogen	"	"	236	"

The quantity of oxygen consumed in these cases varies greatly.

79. *Oxidation at Low Temperatures.*—But the affinity of

Upon what does the heat of combustion depend? What is the example offered? How much water does 1 lb. of charcoal by union with oxygen raise from the freezing to the boiling point? Of wood holding 20 per cent. of water? Of alcohol? Of oil or wax? Of hydrogen?

Does oxidation take place at low temperatures? Does oxygen ever combine with bodies without the production of sensible heat? Is the heat produced the same, whether the iron is burned in oxygen gas or rusted in the air?

oxygen is exerted at low temperatures as well as at high ones; its activity never ceases. It exists in a free state throughout the atmosphere which envelops the globe, and is in constant contact with all forms of matter; attacking every thing with which it is not already combined. This slow combustion, though unaccompanied by light, is always attended with heat, although it may not be in sufficint quantity to be measured. An ounce of iron rusted in the air, or burnt in oxygen gas, produces exactly the same amount of heat in both cases; the difference being, that in the former instance the heat is developed so slowly as to take years, while in the latter case the same effect is produced in as many minutes.

80. The cause of decay in vegetable and animal substances is the action of oxygen upon the elements of which they consist. They are oxidized, or undergo a slow combustion, called by Liebig *eremacausis,* which breaks them up into simpler and more permanent compounds. Oxidation is also the grand process by which air, earth, and sea are cleansed and purified from innumerable contaminations. Putrid vapors and pestilential effluvia are destroyed by a process of burning, more slow, indeed, but as really as if it were done in a furnace. The offensive impurities which constantly pour into rivers, lakes, and oceans are perpetually oxidized by the dissolved gas, and the water is thus kept pure and sweet. This is the reason why waters that have become foul and putrid by absence of air, are sweetened and purified when freely exposed to its action.

81. *Relation of Oxygen to Life.*—But the most interesting relations of oxygen are to the animal kingdom. It is the universal supporter of respiration; and, as this is a vital process, it is a supporter of life. The lungs of land animals

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What is the cause of decay? What is the great cause of purification in air earth, and sea? How is this process effected?

(565) and the gills of fish (559) are both adapted to the same purpose—to absorb oxygen; the one from the air, the other from water. An animal confined in a given bulk of air, having consumed its oxygen, dies. If confined in the same bulk of free oxygen, it lives about thrice as long, and more than ten times as fast. A mouse placed in a jar of oxygen breathes very quick, becomes highly excited, and springs about with the greatest activity. But the effect is too powerful: over-action, fever, and in a short time death, are the result.

82. The chemical action that here takes place is simple oxidation, the same that occurs in the open combustion of fuel, except in a less intense degree. The oxygen combines with the elements of the body, oxidizing or burning them, and the products of the combustion pass from the system by the various channels. Its action upon the living system is the same as upon dead matter, purely destructive. It enters the lungs, is absorbed by the blood, and carried to every part where blood-vessels are to be found. Every organ, tissue, muscle, nerve, and membrane is wasted away, burnt to poisonous gases and ashes, and thrown from the system as dead and useless matter; and if these constant losses are not repaired by the due supply of food, emaciation ensues. The fat being most combustible, is burnt first; the muscles then soften, shrink, and decay; and lastly, the brain is attacked, delirium results, and life ceases. This is called starvation: it is oxidation, absolute burning to death.

83. Such is the relation of oxygen to all the animal races which inhabit the earth. Its action is essentially and always

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How is oxygen related to the animal kingdom? If an animal is confined in a given bulk of air, what results? If in the same bulk of oxygen gas, what ensues? Describe the effects of placing a mouse in a jar of oxygen.

What is the nature of the action of oxygen in this case? How does it affect the system? If food be not taken to repair the waste, what follows? What, then, is starvation?

destructive; and yet it is the sustainer of life—the mainspring of all vital activity. But if this agent enshrouds the globe, and its office be thus only to burn and destroy, it may be asked why it does not speedily reduce all combustible things to ashes, and the earth to desolation. This question will be more properly answered when we come to the chemistry of light and vegetation (337).

84. *Oxidation a Source of Mechanical Power.*—The chemical properties of oxygen are a source of power, which is made use of to produce the greatest mechanical effects. When we say that the affinities of oxygen are energetic, it is meant that, in combining with bodies, it gives rise to vast force. A bushel of coals properly consumed in a steam-engine, produces a power sufficient to raise 70 millions of pounds weight a foot high (J. HERSCHEL). The origin of this prodigious force is the chemical union of almost 200 pounds of oxygen with the carbon of the coal. Oxidation, or the affinity of oxygen for the elements of fuel, is thus the ultimate source of all steam power. Electric currents and the force of electro-magnetism are caused by the combination of oxygen with the metals of the galvanic battery; and in proportion to the activity of this chemical action is the intensity of the effect. In like manner, all muscular force in animals is produced by the oxidation of carbon and hydrogen within the living system (582). Every stroke of the piston—every telegraphic transmission—every motion of the hand—is an exhibition of force which began in chemical changes. Cut off the supply of oxygen, and the steam-engine comes to rest, the galvanic battery ceases to act, and the animal dies.

Are the chemical properties of oxygen a source of power? How much power is produced by the combustion of a bushel of coals? What is the origin of this force? What, then, is the ultimate source of all steam-power? To what are the forces of electricity and electro-magnetism owing? To what is muscular force also due? Remove the oxygen, and what follows?

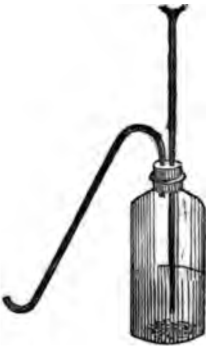
HYDROGEN.

Symbol H, equivalent 1.

85. *Properties.*—Hydrogen is a transparent, tasteless gas, the lightest of all known substances, having about $\frac{1}{14}$th the weight of common air. When pure it is devoid of smell, although, as commonly prepared, it contains impurities, which give to it a disagreeable odor. Hydrogen is never found free in nature, but exists in water, constituting $\frac{1}{9}$th of its weight. It is an essential constituent of all organized substances, vegetable and animal, and is abundantly supplied to plants in water, which they possess the power of decomposing. From its extreme lightness, hydrogen is better fitted than any other substance to inflate balloons, though for this purpose coal-gas, from its greater cheapness, is generally used.

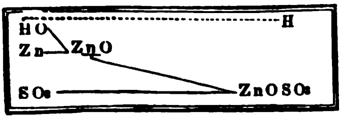
86. *Preparation.*—It is best prepared by the action of dilute sulphuric acid upon bits of zinc. These are placed in a bottle, Fig. 10, to which a cork is tightly fitted. The cork has two tubes inserted. The one for admitting the acid dips beneath the water; the other leads to a pneumatic trough, where the gas is collected in tumblers or jars, in the same manner as oxygen (71). In this case the zinc decomposes the water, and unites with its oxygen, while the hydrogen is set free and escapes. The sulphuric acid dissolves the oxide of zinc as fast as it is formed—thus maintaining a clear metallic surface con-

Fig. 10.



What are the properties of hydrogen? Where is it found?

How is it best prepared? State the changes that take place. How can it be obtained from steam? How does water applied to the forge-fire increase the heat?



tinually in contact with the water. The diagram exhibits these changes. The portions first collected are not to be used, as when mixed with air, hydrogen gas is always explosive. Hydrogen is also obtained by passing vapor of water (steam) through a red-hot gun-barrel, when the oxygen unites with the iron, and the hydrogen is set free. In the same manner, when a blacksmith sprinkles water upon his forge-fire, the red-hot coals decompose it, forming carbonic acid with its oxygen, while the liberated hydrogen burns with the production of increased heat (88).

87. From its extreme tenuity, hydrogen passes through crevices and pores with greater facility than any other substance. Dr. Faraday, in his attempts to liquefy it by pressure, found that it would leak and escape through apertures that were quite tight to other gases; its atoms must therefore be comparatively much smaller. A bell rung in hydrogen is scarcely audible, and when breathed (which, without precaution, is a dangerous experiment) the voice becomes remarkably shrill. Although a gas, and the lightest of all bodies, hydrogen is inferred, from its chemical relationships, to be a metal. Its gaseous form is no objection to this idea, as metallic mercury takes the form of invisible vapor at common temperatures, and other metals may be vaporized by heat.

88. A burning body plunged into hydrogen is extinguished; it is, therefore, a non-supporter of combustion; but, in contact with oxygen, it burns, emits a feeble blue light, and produces an intense degree of heat. The oxy-hydrogen

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What was the result of Dr. Faraday's attempts to liquefy hydrogen? What does this prove? Why is hydrogen gas inferred to be a metal?

Does it support combustion? What is said of the oxy-hydrogen blow-pipe? How blow-pipe is a contrivance for mingling a continuous stream of these gases in an inflamed jet; the light produced by this flame is faint, but the heat is very great. Substances that do not fuse in the hottest blast-furnaces melt in this heat like wax. A small bit of lime of the size of a pea placed within the oxy-hydrogen jet glows with extraordinary intensity (75), producing what is called the Drummond light. This is the light made use of, as a substitute for the sun's rays, in the solar microscope; it is also employed in coast surveys for night-signals. In one case the light emitted by the ball of lime was distinctly visible at a distance of 96 miles (*D. B. Reid*). The heating power of the oxy-hydrogen flame is accounted for by the fact that it is solid, and not hollow like ordinary flame (77), and also that a larger amount of oxygen is condensed by union with hydrogen than with any other element (78).

89. Soap-bubbles blown with hydrogen rise in the air, and may be set on fire with a candle. With a mixture of three parts air and one of hydrogen, when fired, they explode with a loud report; if two parts of hydrogen is mixed with one of pure oxygen, the explosion is very violent and deafening.

90. The term hydrogen signifies *water-former*. If a jet of hydrogen be set fire to, and a cold dry tumbler be held over the flame, the inside of the glass will be instantly covered with a film of dew, which rapidly increases, and at last condenses into drops of water. In all cases where hydrogen is burned with oxygen, water is the product.

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is the Drummond light produced? For what is it used? How far has it been seen? How is the heating power of the oxy-hydrogen flame accounted for?

In what condition does hydrogen explode?

What is the meaning of the term hydrogen? Describe the experiment with the tumbler.

OXYGEN AND HYDROGEN—WATER.

$HO = 9$

91. *Properties.*—This substance, though familiar to all, possesses very remarkable properties, and should be carefully studied. Water is composed of the two gases, oxygen and hydrogen, in the proportion by weight of 8 parts oxygen to one part hydrogen; or by measure, 1 part oxygen to 2 of hydrogen. When pure, it is a tasteless, inodorous liquid; colorless in small quantities, but in large quantities of a splendid ultramarine blue, as when it forms lakes from the melting of Alpine glaciers, and as seen by Parry in the polar regions. It is the most abundant and widely diffused of all chemical compounds. It readily assumes either the solid, liquid, or vaporous state; and with equal facility becomes sweet, sour, salt, astringent, bitter, nauseous, or poisonous, as the substances which it dissolves possess any of these properties. The importance of water, both in the laboratory of the chemist and of Nature, is due to this universal solvent power.

92. *Hydrates.*—Water unites with acids and bases, forming a class of compounds called *hydrates*. These combinations are often attended with heat; water combining with lime develops sufficient heat to ignite wood. Ships at sea have been fired by the accidental wetting of lime in their holds. This heat is caused by the passage of the water from a liquid to a solid state.

93. *The Water-Atmosphere.*—All natural water contains dissolved a certain amount of various gases, which may be expelled by boiling. It then has an insipid, disagreeable

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Why should water be carefully studied? Of what is it composed? In what proportions? What is its color? What is said of its solvent power?

What are hydrates? What is said of the heat produced by these combinations? How is it caused? What is said to be dissolved in all natural waters? What is

taste; but upon being exposed to the air a sufficient length of time, the gases are redissolved, and the water regains its palatable flavor. Oxygen gas is thus absorbed to the extent of about four per cent., and the respiratory apparatus of fish (branchea, or gills) is so arranged (559) that a current of water is constantly flowing in contact with a network of delicate vascular membranes, by which the gas is imbibed: hence, strictly speaking, aquatic as well as land animals breathe the air. On the summits of high mountains, where the air is rarer and more attenuated, less oxygen is absorbed, and hence the lakes in the mountainous valleys of Switzerland and the Andes are destitute of fish.—(*Brande.*)

94. A small quantity of air dissolved in water greatly diminishes its power of dissolving other gases. If water, already saturated with one gas, be exposed to another, the second is absorbed only in proportion as the first escapes. The proportion of different gases taken up by pure water is very variable. Of ammonia it absorbs 780 times its bulk, of hydrochloric acid gas 480, and of carbonic acid an amount only equal to its own volume. Of olefiant gas it dissolves 12·5 per cent., and of nitrogen and hydrogen but 1·6 per cent. of its volume.

95. *Constituents of Common Water.*—Water which has fallen from the clouds as rain, in the country, away from cities and large towns, is the purest we meet with, being contaminated only with the gases which exist in air. But when filtering through the soil and crevices of the rocky strata, it dissolves various earthy salts, which, in many cases, modify its properties very much. River and creek

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the effect of boiling? How much oxygen gas does water contain? Do fish breathe this gas? Why are lakes on high mountains destitute of fish? When water contains one gas and absorbs another, what takes place?

What is the purest water? How does it become impure? What water contains most of these salts?

waters usually contain the least of these salts, spring and well water more, and sea-water and mineral waters the largest quantity.

96. *Hard Water.*—Water derives its quality of hardness from the presence of these substances, chiefly salts of lime (the carbonate and sulphate). A single grain of sulphate of lime will convert 2000 grains of soft into hard water. When common soap is put into hard water, instead of dissolving in it as it does in soft water, it curdles, or is decomposed, and a new soap is formed, which contains lime instead of potash or soda. This new soap will not dissolve, and may often be seen upon the surface in the form of a greasy scum. It adheres to whatever is washed in it, and gives that unpleasant sensation called hardness when we wash our hands. To test this quality of water, dissolve a little soap in alcohol, and place a few drops of it in the water which it is wished to examine. If it remains clear, the water is perfectly soft; if it becomes muddy or opaque, the water is ranked as hard.

97. *Hard Water for Kitchen Use.*—Hard water is a much less perfect solvent than soft water; that is, being already partially saturated, it dissolves additional substances but imperfectly. It is therefore inferior to it for all domestic uses, as tea and coffee making, where solution is to be effected.

98. *Its Effects as a Drink.*—The use of hard water as a drink is unfavorable in dyspeptic affections.—(*Pereira.*) The bad effects of hard water upon the animal system are also seen in the horse. "Hard water drawn fresh from the well will assuredly make the coat of a horse unaccustomed to it stare, and it will not unfrequently gripe and otherwise injure him."—(*Youatt.*)

To what does water owe its hardness? What is the effect when soap is put into hard water? How may we test this quality?

Why is hard water inferior to soft for domestic purposes?

99. *Sea-Water.*—The solid constituents of sea-water amount to about 3½ per cent. of its weight, or nearly half an ounce to the pound. Its saltness may be considered as a necessary result of the present order of things. Rivers which are constantly flowing into the ocean contain salts varying in amount from 10 to 50 and even 100 grains per gallon. They are chiefly common salt, sulphate and carbonate of lime, magnesia, soda, potash, and iron; and these are found to be the main constituents of sea-water. The water which evaporates from the sea is nearly pure, containing but very minute traces of salts. Falling as rain upon the land it washes the soil, percolates through the rocky layers, and becomes charged with saline substances which are borne seaward by the returning currents. The ocean, therefore, is the great depository of every thing that water can dissolve and carry down from the surface of the continents; and as there is no channel for their escape, they of course constantly accumulate.

100. The continuance of this process for numberless ages must inevitably have produced a highly saline condition of the ocean. "The case of the sea is but a magnified representation of what occurs in every lake into which rivers flow, but from which there is no outlet except by evaporation. Such a lake is invariably a salt lake. It is impossible that it can be otherwise; and it is curious to observe that this condition disappears when an artificial outlet is produced for the waters."—(*Fownes.*)

101. *The waters of the Dead Sea* are much more salt than those of the ocean. It is situated at the bottom of an

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What proportion of solid matter is contained in sea-water? From whence is it derived? What are these salts chiefly? Why do these salts accumulate in the sea? What is the condition of lakes that have no outlet but by evaporation? What is the effect of creating an artificial outlet?

What is said of the Dead Sea?

immense basin or valley several hundred feet lower than the Mediterranean Sea, and has no outlet. The streams of water which flow into it do not raise its level, in consequence of excessive evaporation. Its condition is well described by a recent traveller. "When bathing in its waters I floated upon the surface like a log of wood, without stirring hand or foot. With much exertion I could dive sufficiently deep to cover all my body, when I was thrown out again to the surface, in spite of all my efforts to descend lower. On coming out of the water, I found my body covered over with an incrustation of salt the thickness of a sixpence."

102. *Mineral Waters.*—These are such as contain saline substances in the largest proportion. Those which abound in the salts of iron (carbonates and sulphates of iron) are called *chalybeate* or *ferruginous* waters. If the waters are brisk and sparkling, carbonic acid gas is present, and they are called *carbonated* or *acidulous* waters. If the active ingredient be sulphur, the spring is termed *sulphurous.* If the odor of decayed eggs, or the scourings of a foul gun-barrel is exhaled, the waters are charged with sulphuretted hydrogen. The water of the celebrated Congress Spring, at Saratoga, contains, according to Allen's analysis, the following ingredients in a gallon:

Chloride of sodium	390,246 grs.
Hydriodate of soda and bromide of potassium	6,000 "
Carbonate of soda	9,218 "
Carbonate of magnesia	100,941 "
Carbonate of lime	103,416 "
Carbonate of iron	1,000 "
Silex and alumina	1,086 "
Total solid contents	611,852 grs.

What are chalybeate waters? What are acidulous? What sulphurous? What are the main constituents of Congress water?

Carbonic acid	886,188 grs.
Atmospheric air	3,261 "
Total gaseous contents	889,449 grs.

103. *Organic Impurities in Water.*—All natural waters, even those which fall from the clouds according to Liebig, contain traces of decomposing organic matters in variable quantity. To this they owe the quality of becoming putrid when kept. In many cases, it is present in such quantity as to injure health, derange the bowels, and often produce violent dysentery. Stagnant waters, abounding in putrescent matter, contain numberless minute animals (*animalcula*), which are sometimes exhibited by means of the solar microscope; they are not found in the waters commonly used for drink.

104. *Purification of Water.*—The best method of purifying water is by *distillation* (64). This is effected by passing the steam from one vessel into another, which, being kept cool, condenses it: to render it perfectly pure, it must be redistilled at a low temperature in silver vessels. By filtration through sand, or other closely porous media, water may be deprived of suspended impurities, and of all living beings. Boiling kills all animals and vegetables, expels the gases, and precipitates carbonate of lime, which constitutes the fur or crust often seen lining tea-kettles and boilers. Alum (two or three grains to the quart) cleanses turbid or muddy water. The alum is decomposed by carbonate of lime, and the alumina set free, carries down the impurities mechanically; but the sulphuric acid of the alum, combining with the lime, forms sulphate of lime, and makes the water harder than

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What is said of the organic matters contained in water? Does common drinking water contain animalcula?

How is water best purified? What is the effect of filtration? Of boiling? Of alum? Of the alkalies potash and soda?

before. The alkalies, potash or soda, soften water. They decompose and precipitate the earthy salts, leaving in solution an alkaline salt, which does not harden it.

105. *Effect of Leaden Vessels upon Water.*—Water sometimes becomes poisonous by contact with lead, as when lead pipes, cisterns, roofs, gutters, &c., are used. The purer the water, the more liable it is to become impregnated with lead, as the presence of earthy salts in solution exerts a protecting influence. Spring and well waters are, therefore, less liable to this contamination than rain-water, which is purer. Water which tarnishes polished lead, when left at rest upon it in a glass vessel for a few hours, or which contains less than about $\frac{1}{8000}$th its weight of salts in solution, cannot be safely transmitted through lead pipes without certain precautions. The best remedy, where there is danger, is to leave the pipes full of water at rest for three or four months, or to substitute for the water a weak solution of phosphate of soda.—(*Christison.*)

106. *Necessity of Water to Organized Beings.*—To the organic kingdom water is an agent of the first necessity, as its abundance and scarcity regulate the distribution of animals and plants over the globe. Its properties seem to mark out the plan of animated nature. From the highest animal, to the meanest vegetable that can grow on a bare rock, this ingredient is absolutely required. It is an essential constituent of all parts of living bodies, forming upwards of one-half the weight of all newly gathered vegetable substances cultivated by man.

Is pure or impure water most liable to become poisoned by contact with lead? How can we determine whether lead will be acted on by water? What is the best remedy where there is danger?

What is said of the importance of water to the organic kingdom?

In what two states does water exist in organic bodies?

What is the office of water in the growth of plants? What is the proportion of water in blood? In flesh?

107. Water exists in most organized bodies in two separate states. In one it may be regarded as an essential portion of the substance, as of sugar or starch in their dryest state (349), from which it cannot be separated without breaking up the compound. In the other state, it is associated with bodies so loosely that it may be removed by drying. The quantity that may be thus separated from various articles of diet, without injury to the compound, is as follows: Wheat 14·5 per cent., rye 16·6, oats 20·8, barley 13·2, Indian corn 18, peas 16, beans 14·11, potatoes 75·9, turnips 92·5, carrots 87·6, beet-root 87·8, white cabbage 92·3, blood 80, muscle of beef 74, of veal 75, of mutton 71, of pork 76, of chicken 73, trout 80·5 per cent.—(*Pereira.*)

108. Both gases and the mineral elements of soils enter the roots of plants dissolved in water. As sap, this water circulates through the various organs, carrying and depositing the newly formed substances, yielding up its own elements, and ministering perpetually to the growth of the plant.

109. In animal systems the use of water is equally important (495). It is the natural drink of all adults, being the liquid employed in the body to dissolve and distribute the food. Eighty per cent. of the blood (*Liebig*) and seventy-four per cent. of flesh (*Brande*) consist of water; while, to repair the constant waste and loss from the system, an adult man requires about three-fourths of a ton per year (*Draper*). The softness, pliancy, and symmetrical fulness of the animal body, is produced by the liquids of which it is chiefly composed. The tendency of flesh or fresh meat to putrefaction, is caused by the large quantity of watery

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How much does a man consume annually? What gives symmetry and fulness to the animal form? How does water cause putrefaction in flesh? How is it checked?

juices it contains. As solution favors chemical action (29), putrefactive changes readily set in; but are checked if the flesh be dried, as is often done for the preservation of meats.

110. Under ordinary circumstances, water freezes at 32°, and boils at 212°; it retains its liquid condition, therefore, through a range of 180°; and, as in this state only it can exist in animals and plants, these limits mark the thermal conditions upon which living beings can continue on the earth.

111. A cubic inch of water forms very nearly a cubic foot of steam. Water occupies the smallest space, or is most dense at 39·83° F.; if its temperature varies from this point, in either direction, it expands in bulk; this is called the point of maximum density of water. In freezing, water expands very much, and exerts so great a force as to burst the strongest vessels in which it is contained. It is thus that the surface of the hardest rocks is crumbled down into soil fit for the support of vegetable life; the water, percolating into minute crevices and fissures in summer, freezes in winter, and expands with a force which breaks the solid stone.

112. Snow does not quench thirst, but rather increases it; and the natives of the arctic regions "prefer enduring the utmost extremity of this feeling, rather than attempt to remove it by the eating of snow."—(*Capt. Ross.*)

113. The specific gravity of ice is 0·92 (*Silliman*); it therefore floats upon the surface of water. If it sank as fast as it is formed, whole bodies of water would be con-

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Within what limits does water maintain its humidity? What relation has this property of water to life?

A cubic inch of water forms how much steam? At what temperature is it most dense? Does water expand in freezing? At what temperature is it most dense? How does this property of water affect rocks?

What is the specific gravity of ice? If it were heavier than water, what would verted into solid ice. During freezing the substances dissolved in water are expelled, hence the ice of sea-water (as is well known to sailors), when melted, forms fresh water. Water from melted snow, for the same reason, contains no air or gas; hence fish cannot live in it (*Pereira*). One imperial gallon of water weighs 70,000 grains, or just ten pounds. The American standard gallon holds 58,372 American Troy grains of pure distilled water, at the maximum density. One cubic inch weighs 252·458 grains, which is 815 times as much as an equal bulk of atmospheric air (*Silliman*). A cubic foot of water weighs very nearly 1000 ounces avoirdupois (998·2 oz. *Brande*).

DEUTOXIDE OF HYDROGEN.

$HO_2 = 17$.

114. This curious compound is formed by chemists, with difficulty, by adding to water another equivalent of oxygen. It is a syrupy liquid, of a disagreeable odor, a nauseous, bitter, astringent taste, and is not frozen by intense cold. It is easily decomposed, often with an explosion, and sometimes with a flash of light. As yet, it is of no use.

NITROGEN (*Azote*).

Symbol N, *equivalent* 14.

115. *Properties and Sources.*—Nitrogen is a permanently elastic gas, destitute of either taste, smell, or color; slightly lighter than the air, and remarkable for its negative

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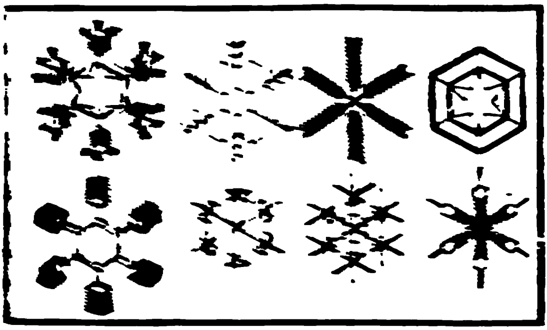
be the result? What is said of the ice of sea-water? Of water from melted snow? What is the weight of a gallon of water? Of a cubic inch? A cubic foot?

What is the composition of deutoxide of hydrogen? Its properties? Uses?

Fig. [illegible]



[illegible]. *Additional Substances in the Air.*—Liebig has shown that the air also contains minute traces of ammonia, which are washed down, and may be detected in rain-water. Indeed, as the sea contains a little of every thing that is soluble in water (49), so the atmosphere may be conceived to contain a little of every thing that is capable of assuming the gaseous form. The odorous emanations of plants, the miasms of marshes, and principles of contagion, though all producing effects upon the human body, cannot be collected from the air, nor even their presence detected by chemical tests. It is supposed that these substances do not exist in the true gaseous state, but are composed of fixed organized particles which float about suspended in the atmosphere, like the pollen of flowers. They are all, however, oxidized and destroyed, as the air contains within itself the means of its own purification.

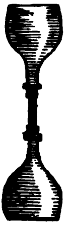
[illegible]. *The Law of Gaseous Diffusion.*—The oxygen and

What other substances naturally find their way into the atmosphere? In what form are many of these substances supposed to exist?

Is the atmosphere a chemical compound? By what law is the intermixture of its gases regulated? How is the operation illustrated?

nitrogen gases, of which the air is chiefly composed, are not chemically united with each other, but only mixed together mechanically. If we mingle them in a vessel in the same proportions, we get an artificial air, having the same properties as the natural air. This uniform intermingling of the gaseous elements is brought about by what is called the law of *gaseous diffusion*. Its operation may be thus shown: two vessels are to be placed one above the other, and connected by a narrow tube of any convenient length (Fig. 15). The lower vessel may be filled with carbonic acid gas, and the upper vessel with hydrogen gas. After a short time the carbonic acid, although twenty times heavier than the hydrogen, will be found to have ascended into the upper vessel; while hydrogen will have descended into the lower one,—a complete intermixture of the two gases in equal proportions having taken place against the action of gravity.

Fig. 15.



137. This effect will be produced even though a barrier, as a membrane of India-rubber, intervene. The force with which gases thus diffuse into each other is very great. Dr. Draper has proved that sulphuretted hydrogen will diffuse into atmospheric air, though resisted by a pressure of fifty atmospheres, equal to the weight of a column of water more than 1500 feet in height. In like manner, all gases possess the power of diffusing into each other, although at different rates of velocity, depending upon their density: the lighter the gas, the more rapid is the diffusion.

138. This principle is of the utmost importance in relation to the air, because if either of its constituent elements were to separate from the mass, the extinction of life would

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What is said of the force with which gases diffuse into each other?
Why is this principle of the greatest importance?

less perfectly than oxygen, and combines directly with the metals, forming a class of bodies called chlorides. It is found abundantly in nature, existing in common salt to the amount of 65 per cent. in union with sodium. Chlorine is best prepared by the action of three parts of hydrochloric acid upon 1 part of black oxide of manganese, in a flask, by the aid of heat. The decomposition may be traced in the accompanying diagram. It may be collected in the pneumatic trough over hot water or strong brine, but is absorbed by cold water. It may also be collected by carrying the tube to the bottom of an open vessel; the chlorine rises and expels or displaces the air (Fig. 16).

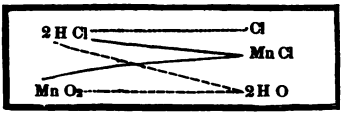
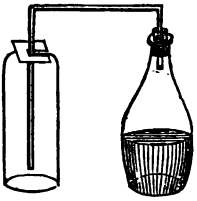


Fig. 16.



143. *Bleaching Properties of Chlorine.*—It is easily dissolved in cold water, and in this state exerts a remarkable bleaching power over vegetable colors. It is principally used in bleaching cotton cloth and paper. The bleaching-powder of commerce is chloride of lime. Chlorine is also a powerful disinfectant, and is used to destroy the bad effluvia of sick rooms; but in these cases it requires to be used with caution, as it is excessively irritating to the lungs. Its bleaching and disinfecting properties are due to its strong affinity for hydrogen, which it takes away from coloring and putrescent substances, thus decomposing them entirely.

What is chlorine? What are its properties? Where is it found? How obtained? How may it be collected? Explain the changes.

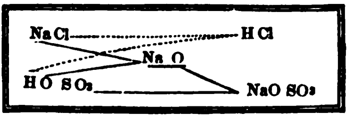
How does chlorine affect vegetable colors? To what other use is it applied? To what does it owe its bleaching and disinfectant properties?

144. Humboldt discovered that chlorine possesses the power of quickening the germination of seeds. Old seeds, which could be made to grow by no other process, germinated promptly when steeped in a weak solution of chlorine in water. Chlorine is said, when respired in very minute quantity, to alleviate the symptoms of consumption. It is also stated that workmen employed in bleaching establishments, and other places where chlorine is used, are less liable to this disease than others.

HYDROCHLORIC ACID (*Chlorohydric Acid, Muriatic Acid*).

$HCl = 36{\cdot}5$.

145. When hydrogen and chlorine gases are mixed in the dark, they do not unite; but exposed to diffused daylight, they gradually unite, and if to direct sunshine they combine explosively, forming hydrochloric acid, which is a transparent, colorless gas, having intense acid properties. It is usually prepared by adding oil of vitriol to common salt, and submitting the mixture to the action of heat. Its ordinary form is a liquid solution, as it very freely dissolves in water. Salts formed from it are called muriates, or hydrochlorates. This acid exists in the gastric juice, and assists in dissolving the food.



For what other purposes has chlorine been used?
What is hydrochloric acid, and how is it formed? What are its salts called? Where is it found?

FLUORINE.

Symbol F, *equivalent* 18·70.

146. Fluorine exists combined with calcium, as fluoride of calcium, or fluor spar. In this state it is a minute ingredient of bones, especially of the enamel of the teeth. It has never yet been separated, but is supposed somewhat to resemble oxygen in its properties, as it does not form a compound with it. Fluorine combines with hydrogen, forming hydrofluoric acid, which is remarkable for its property of corroding glass.

IODINE.

Symbol I, *equivalent* 126·36.

147. Iodine is a grayish-black solid, of a metallic appearance, resembling black-lead. It is obtained chiefly by leaching the ashes of sea-weed (kelp), but it sometimes occurs in the waters of springs. It dissolves freely in alcohol, but very sparingly in water, has a smell similar to chlorine, and combines with starch, forming a deep blue compound (iodide of starch). It stains the skin brown, and yields a fine purple vapor when heated. If a polished silver plate is held over this vapor, it first becomes of a yellow color, then violet, then of a deep blue, owing to the combination of the iodine with the silver. The iodide of silver thus formed is decomposed by light. The daguerreotype process depends upon this principle.

What is said of fluorine?

What is iodine? How is it obtained? What are its properties? What is said of its vapors?

BROMINE.

Symbol Br, *equivalent* 78·26.

148. Bromine is a heavy, brownish-red liquid, of a suffocating odor, and is derived, like iodine, from the sea. Both iodine and bromine combine with metals, like chlorine, forming iodides and bromides. They also unite with hydrogen, forming acids—the hydriodic and hydrobromic acids. Iodine and bromine are also used medicinally in the treatment of scrofula and for dispelling tumors.

CARBON.

Symbol C, *equivalent* 6.

149. This important substance is familiarly known as charcoal. It is widely diffused in nature, and is the solidifying element of all living structures. By casting the eye upon the Chart, we see at once that it belongs chiefly to the organized kingdom, constituting about one-half the weight of dry vegetable and animal substances. Carbon exists in several allotropic forms (42), displaying properties remarkably different in each case.

150. *The Diamond.*—This is the purest state of carbon. It is a crystal, having the figure of two pyramids applied base to base. The diamond is the hardest substance known, and can only be wrought, or cut, by rubbing one against another, or by the use of diamond dust. Diamonds are ground or cut, usually, into two forms, by means of diamond powder worked with olive oil upon a wheel of soft steel. The *rose diamond* is cut into a hemispherical form, but rises to a point,

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What is bromine? For what is it used?

What is carbon? What fact does a glance at the Chart communicate concerning carbon?

What is the diamond? How are diamonds cut? Why cut thus? What is the

and has twenty-four flat, triangular faces (facets); these facets reflect the light, and give the gem a glittering appearance. The ***brilliant*** is cut with a flat face, or table, upon the top, surrounded with facets; it has the finest effect, but requires the sacrifice of a larger portion of the gem. A brilliant-cut diamond is esteemed equal in value to a rough one of twice the weight, besides the cost of working it. Diamonds are of various colors, but the most valuable are colorless and limpid. The snow-white, transparent diamond, is said to be of the *first water.*

151. *Value of Diamonds.*—Diamonds are sold by the carat, a carat being equal to four grains.—(*Ure.*) They increase in value not in proportion to their weight, but in proportion to the *square* of their weight. Thus, the value of three diamonds weighing 1, 2, and 3 carats, is as 1, 4, and 9. The average value of wrought diamonds weighing one carat is $40 (*Brande*); one of two carats will be valued at $160; three carats, $360; 100 carats, $400,000.

152. The largest known diamond is probably that called the *Kooh-i-noor* (mountain of light), of the East Indies. It was discovered in the mines of Golconda just 300 years ago. When rough it is said to have weighed 900 carats. It is of the rose form, and was reduced to 279 carats by cutting. It has caused several wars, and has been six times violently wrested from its possessors. The British have at last seized it, and transferred it to England, that the benighted pagans may stop quarrelling about it (!). It has never been sold, but $10,000,000 is talked of as the price, equal to about seventeen tons of gold.

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form of the rose diamond? What of the brilliant? What are diamonds of the *first water*?

How are diamonds sold? What determines their value?

What is the history of the Kooh-i-noor?

153. *Uses of the Diamond.*—From its extreme hardness, the diamond is used for cutting glass, for drilling apertures through other gems, for the pivot-holes of delicate watch-work, also to form the holes through which extremely fine wire is drawn. It refracts light powerfully, and has been used for the lenses of microscopes. The diamond is very difficult of combustion, but may be burned in pure oxygen gas. Pepys sealed up a diamond in a piece of pure soft iron, and exposed it for some time to an intense heat; when examined, the diamond had disappeared, and the iron was converted into steel, which is composed of carbon and iron. The diamond is thus known to be pure carbon.

154. *Plumbago, Graphite, or Black-Lead.*—This is another form of carbon, having a metalline appearance, and containing a small proportion of iron. It resists quite a high degree of heat, and is used to make crucibles. It is also used for marking on paper, being sawn into slices and fitted into the grooves of *cedar pencils*, or rounded for *ever-pointed pencils.* It is also employed to relieve the friction of machinery, instead of oil or grease; also for giving lustre to iron, as stove-blacking. In this form it is often adulterated with 50 per cent. of lamp-black, which may be detected by exposing the suspected article for some time to a cherry-red heat, in the open air. The lamp-black will burn away, and its amount may be determined by the loss of weight.

155. Another variety of carbon is *lamp-black.* It is the soot deposited from the flame of pitchy or tarry combustibles. It is usually made by burning the refuse rosin left by the distillation of turpentine. The smoke is conducted

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For what is the diamond used? Is it combustible? How is it proved to be pure carbon?

What is plumbago? What are its uses? What is said of stove-blacking? How is the cheat detected?

What is lamp-black? How is it made? For what is it used?

through long horizontal flues, terminating in chambers hung with old sacking, upon which the lamp-black is deposited. It is used for making printers' ink and black paint.

156. *Charcoal* is that species of carbon which is produced by burning vegetable or animal substances out of contact with the air. Every one knows it is a black, inodorous, insipid, insoluble, brittle substance, applied to numerous uses. Common charcoal is made by piling billets of wood together in a conical heap, covering it with earth, and burning the mass slowly, with but a partial access of air. By the usual process of coal-burning in forests, about 18 per cent. of the weight of the wood is obtained (*Ure*), although the amount varies greatly.

157. Charcoal seems to be soft; but if the fine powder, in small quantity, be rubbed between plates of glass, it is found that the little particles are very hard, and able to scratch the glass almost as easily as the diamond itself.—(*Norton.*)

158. *Charcoal as Fuel.*—Charcoal is very combustible, and is extensively used for fuel. When pure, it burns without flame, although it usually contains water, which, during the combustion, is partially decomposed into carburetted hydrogen, which burns with a slight flame. A cubic foot of charcoal from soft wood weighs, upon an average, from eight to nine pounds; and from hard wood, twelve to thirteen pounds. Hence the hard-wood coal is best adapted to produce a high heat in a small space. Yet equal weights of the different charcoals yield equal quantities of heat. Upon an average, a pound of dry charcoal will heat 73 pounds of water from the freezing to the boiling point.—(*Ure.*)

What is charcoal? What are its properties? How is it made? What per cent. of charcoal is obtained from a given weight of wood by this process?

What is stated concerning the hardness of charcoal?

To what is the slight flame sometimes seen upon burning charcoal due? What is its weight? Upon what does the value of charcoal, as fuel, depend?

159. *Charcoal very indestructible.*—Charcoal is a very unchangeable substance, as it is not affected at common temperatures by air or moisture. The beams of the theatre at Herculaneum were converted into charcoal 1700 years ago, when that city was overwhelmed with lava, and remain as entire as if they had been charred but yesterday. Wooden stakes or piles are rendered more durable by charring upon the surface, before driving them into the ground. Most of the houses in Venice stand upon piles or stakes, the extremities of which are charred for their better preservation. Oaken stakes have been recently found in the bed of the Thames River, where they are supposed to have been driven at the time of the invasion of Julius Cæsar. They were charred to a considerable depth, and were firm at the heart.

160. *Absorbent Property of Charcoal.*—Charcoal possesses, in a remarkable degree, the power of absorbing different gases, and condensing them within its pores. It will absorb 90 times its bulk of ammonia, 35 times its bulk of carbonic acid, of oxygen 9 times, and of nitrogen 7 times its bulk (*Saussure*). When charcoal already saturated with one gas is put into another, it gives out a portion of the gas already absorbed, and takes up a portion of the new gas. Recently burned charcoal imbibes watery vapor from the air very greedily. By a week's exposure to the atmosphere, it thus increases in weight from 10 to 20 per cent. This property of absorption varies with different kinds of charcoal. It is possessed in a higher degree by those containing the most pores, that is, where the pores are finer, and in a lower degree by the more loose and spongy sorts. "A cubic inch

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What is the effect of surface-charring upon the durability of wood? Examples. What property does charcoal possess to a remarkable degree? What kind of charcoal is the most absorptive? What extent of internal surface has a cubic inch of charcoal? Where are the gases condensed?

of charcoal," says Liebig, "must have, at the least computation, a surface of 100 square feet." It is upon this interior pore-surface that the gases are condensed, and in proportion to its extent is the quantity absorbed.

161. Other substances besides charcoal, in fact all solids, porous or otherwise, are supposed to possess, in various degrees, this power of condensing gases upon their surfaces. The black powder of platinum absorbs 800 times its bulk of oxygen gas. The gas in this case must be condensed almost to the condition of a liquid. If now a jet of hydrogen is projected upon the platinum, it unites with the oxygen, heat is liberated, water formed, and the metal becomes red-hot. Faraday has lately shown that the porous condition of the platinum is not necessary, as a similar effect may be produced by a clean bright slip of the metal.

162. *Preservative Power of Charcoal.*—Connected with this property is the power which charcoal possesses of removing offensive odors and checking putrefaction. It is a powerful antiseptic. Charcoal-powder, newly prepared, when rubbed upon tainted meat, restores it to sweetness. By charring the inside of casks, water may be kept in them a long time without spoiling. Vegetable substances containing much water, as potatoes, are more completely preserved by the aid of a quantity of charcoal. The bad odor sometimes acquired by clothes is removed by wrapping them with charcoal. Filters are constructed for purifying water, by passing it through layers of charcoal of different degrees of fineness.

163. *Bone-black.*—The charcoal from bones is called *bone-black* or *ivory-black*, and is of course loaded with mineral

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Do other substances possess this power?

What is stated of the antiseptic or preservative properties of charcoal? In what way is it used for this purpose?

atter (phosphate of lime); but for clarifying purposes, it superior to wood charcoal. It is extensively used in sugar efining to discharge the color of the raw article. Vinegars, wines, and syrups are also decolorized by the same agent. Payen has recently shown that this power of the charcoals depends upon the more or less complete state of subdivision among their particles, and that animal charcoal is superior to vegetable only because its mineral matter serves to keep the carbon particles further apart. The beneficial use of charcoal upon soils, and in the manufacture of artificial manure (*Poudrette*), is explained by this property of absorption.

164. *Other Uses.*—Charcoal is also used for making gunpowder and fireworks, and, being a bad conductor of heat, for casing iron steam-pipes. Some varieties contain silex (sand), and are used for polishing metals. Charcoal is of great value in separating metals from their oxides in the smelting furnace, as, at a high temperature, it has a powerful affinity for oxygen.

165. *Coke.*—This is a black, porous mass left after heating pit coal with the air excluded, as is done in iron retorts for the manufacture of illuminating gas (177). It ignites with difficulty, but is capable of producing, by its combustion, a higher temperature than any other fuel, bulk for bulk. *Spanish black* is the charcoal of cork. *Black crayons* are made from the charcoal of the willow.

166. *Source of the Carbon of Plants.*—Plants derive their carbon from carbonic acid, most of which they absorb from

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What is bone-black? For what is it employed? Why is this superior to vegetable charcoal?

Mention some other uses of charcoal.

What is coke? Its properties? What is Spanish black?

Whence do plants derive their carbon? What was formerly supposed concerning it?

168. *Solid Carbonic Acid.*—Under a pressure of 36 atmospheres (upwards of 500 pounds on the square inch), carbonic acid shrinks into a colorless liquid of sp. gr. 0·83, at 32°. When this pressure is suddenly removed from the liquid acid, it expands into a gas with such rapidity, that one portion absorbing heat from the other, freezes it into a white, filamentous solid. This solid carbonic acid, when dissolved in ether and evaporated, produces the most intense cold known (67).

169. *Sources of Carbonic Acid.*—Carbonic acid is produced very abundantly in nature. The burning of fuel (which always contains carbon) in the open air yields it in vast quantities. The combustion of a bushel of charcoal produces 2500 gallons of this gas. It is also formed within the bodies of all animals, by the union of atmospheric oxygen with the carbon contained in the system, and escapes through the lungs, by respiration, into the air. Each adult man exhales about 140 gallons per day.—(*Davy.*) Its quantity varies at different times, being greatest after a meal, and least during sleep and fasting. Children exhale more carbonic acid, in proportion to their weight, than adults. About 4 per cent. of the inspired oxygen is converted into carbonic acid at each respiration; and the bulk of carbonic acid formed is exactly equal to that of the oxygen consumed in producing it.

170. The test of carbonic acid is clear lime-water, which it turns milky, by forming insoluble carbonate of lime. To prove that it is produced both by combustion and respiration, invert an empty jar over a burning candle for a short

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What pressure converts it into a liquid? How is this liquid frozen?

Mention some of its sources in nature. How much does an adult man exhale daily? What per cent. of the inspired air is changed to carbonic acid?

What is the test of carbonic acid? How is it proved that it is produced both by combustion and respiration?

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METALS EMPLOYED IN THE ARTS.

IRON. (*Latin, Ferrum.*)

Symbol Fe, *equivalent* 28.

225. Were we to seek for that circumstance which might best illustrate the peculiarities of ancient and modern civilization, we should perhaps find it in the history of this metal. The ancients, imbued with a martial spirit and passion for conquest, regarded iron as the symbol of war, and gave it the emblem of Mars. And if it were required also to symbolize the pacific tendencies of modern society—its triumphs of industry and victories of mind over matter, its artistic achievements and scientific discoveries—we should be compelled to make use of the same metal, IRON. As gold and jewels have long been the type of ignorant and empty pomp, so iron may now be well regarded as the emblem of beneficent and intelligent industry.

226. *Uses of Iron.*—Iron, in some of its innumerable forms, ministers to the benefit of all. The implements of the miner, the farmer, the carpenter, the mason, the smith, the shipwright, are made *of* iron, and *with* iron. Roads of iron, travelled by "iron steeds," which drag whole townships after them, and outstrip the birds, have become our commonest highways. Ponderous iron ships are afloat upon the ocean, with massive iron engines to propel them; iron anchors to stay them in storms; iron needles to guide them; and springs of iron in chronometers, by which they measure the time. Ink, pens, and printing-presses, by which knowledge is scattered over the world, are alike made of iron. It warms us in our apartments; relieves our jolts in the carriage; ministers to our ailments in the chalybeate mineral

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How did the ancients regard iron? Of what may it now become the symbol? Enumerate some of the uses that are made of iron.

waters, or the medicinal dose; it gives variety of color to rocks and soils, nourishment to vegetation, and vigor to the blood of man. Such are the powers of a substance which chemists extract from an otherwise worthless stone.

227. *Properties of Iron.*—Iron is of a grayish-white color, and of a perfect lustre when polished. It may be thrown into many conditions, in which it exhibits remarkably different properties. It is malleable, as in bar or wrought iron; and may be forged into any form under the hammer. It is very ductile, and may be drawn out into the finest wire, which is extremely tenacious (tough); an iron wire $\frac{1}{36}$ of an inch in diameter bearing a weight of sixty pounds.

228. *Welding of Iron.*—When wrought-iron is heated to whiteness, it becomes soft, pasty, and adhesive, and two pieces in this condition may be incorporated or hammered together into one. This is called *welding.* During the heating, a film of oxide is formed upon the surface of the metal, which would obstruct the ready cohesion of the separate masses. To prevent this, the smith sprinkles a little sand upon the hot iron, which combines with the oxide, forming a fusible silicate of iron, which is easily forced out by pressure, leaving clean surfaces that unite without difficulty. This important quality is enjoyed only by iron, platinum, and sodium. All the other metals pass suddenly from the solid to the liquid state at their respective melting points, as ice is changed to water.

229. *Wrought and Cast Iron.*—Wrought-iron possesses what is called a *fibrous texture;* that is, it seems to consist of compacted threads, running parallel to each other like the fibres of flax. Another state of the metal is *cast-iron*, which,

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What is the appearance of iron? Name some of the conditions it may assume.

What is welding? Have all metals this property?

What is the texture of wrought-iron? What of cast-iron? What is said of the iron is exposed to moist air, it soon becomes covered with a red crust, which is the sesquioxide of iron, $Fe_2 O_3$; it is also called the peroxide. This oxide gradually absorbs water, turns of a yellowish color, and forms rust, which is hydrated peroxide of iron. These colors are well shown in bricks, which before burning are of a yellow color, owing to the hydrated peroxide of iron in the clay. Heat expels the water from the peroxide, which colors the bricks red.

240. These compounds of iron are the most abundant oxides in nature, existing in numerous stones, rocks, and soils, and are the cause of their red and yellow colors. Protoxide of iron, $Fe O$, cannot be produced in a separate state, as it attracts oxygen and rapidly passes into the peroxide. In a state of combination it is widely diffused in nature, existing chiefly in those rocks having a greenish or dark tint. The iron in mineral waters (*chalybeate springs*) usually rises to the surface in the form of a protoxide; after a brief exposure to the air more oxygen is absorbed, and a reddish scum is formed upon the surface, which gradually falls to the bottom of the current as a reddish sediment of insoluble peroxide.

241. When iron is heated in the smith's forge, and then beat on the anvil, a scale flies off which is of a black color, and when crushed gives a black powder: this is the black oxide, and is supposed to be a combination of the two other oxides, $Fe O + Fe_2 O_3$. Gallic acid, with $Fe_2 O_3$, gives a black precipitate (writing-ink); chlorine water and oxalic acid remove it.

242. Iron rusts rapidly in water containing air (oxygen),

What gives to brick their yellow color before being burned? Why are they red after they are burned?

What is said of the abundance of these oxides? Why cannot the protoxide of iron be easily obtained in a separate state? Of what is the reddish sediment in chalybeate springs composed?

What is black oxide of iron? What is ink composed of?

or the slightest trace of acidity. But in water which has been deprived of air by boiling, or rendered alkaline by lime, ammonia, potash, or soda, it is not rusted, but retains its polish for years.—(*Brande.*) *Galvanized iron* is made by dipping iron, the surface of which has been cleaned, into a bath of melted zinc, and then into another of melted tin. The coating thus given prevents rust. When cast-iron, as cannon, for example, has been long buried in the sea, it becomes lighter, and is changed into a substance resembling black-lead. The iron in this case has probably been dissolved by chlorine from the sea-salt. Cast-iron is rendered malleable by heating it for a considerable time with iron scales or oxide. It is thrown into the market under the name of malleable iron.

MANGANESE.

Symbol Mn, *equivalent* 27·67.

243. Manganese is a hard, brittle metal, of a grayish-white appearance, much like cast-iron. It never occurs pure in nature, but its oxides are found combined with many ores of iron, a metal which it resembles in many of its properties. Manganese is prepared by making its oxide into a paste with oil and lamp-black, and heating it to whiteness in a covered crucible. It rapidly oxidizes when exposed to the air, and is best preserved in naphtha.

244. It forms no less than seven different compounds with oxygen. Its oxides are diffused in small quantities through nearly all soils, and traces of them may be detected in the ashes of most plants. Protoxide of manganese is of a pale-green color, is a powerful base, giving rise to rose-colored

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How is galvanized iron made? What is said of iron long buried in the sea? How is cast-iron rendered malleable?

What is manganese? What metal does it resemble? How is it prepared?

barometers, thermometers, mirrors, &c. When heated nearly to its boiling point, and exposed to the action of air, it absorbs oxygen, and is converted into the peroxide of mercury (red oxide), which, when heated, evolves oxygen, and is reduced to a metallic state. It was from this source that Priestley first obtained oxygen gas. Mercury combines with chlorine in two proportions, forming the protochloride of mercury, $Hg\,Cl$ (calomel), and the bichloride, $Hg\,Cl_2$ (corrosive sublimate). The latter has a disagreeable, acrid, metallic taste, and is very poisonous. The proper antidote is white of egg, which forms with it an insoluble, inert compound.

SILVER. (*Latin, Argentum.*)

Symbol Ag, *equivalent* 108.

253. Silver occurs native, both uncombined and as a sulphuret and chloride. It is the whitest of the metals, and has a bright, beautiful lustre. It is very malleable and ductile. It may be extended into leaves not exceeding $\frac{1}{10000}$ of an inch in thickness, and one grain may be drawn out into 400 feet of wire. It is used chiefly for coinage and silver plate. Silver does not tarnish in air or water. It forms compounds with oxygen, sulphur, chlorine, iodine, and bromine, all of which are darkened by the action of light, a property which is made use of in the daguerreotype process.

PLATINUM.

Symbol Pt, *equivalent* 98·68.

254. This very valuable metal is of a whitish-gray color, somewhat resembling silver. When pure, it scarcely yields

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For what is mercury used? What is the composition of calomel? What is the composition of corrosive sublimate?

Describe silver. What is said of its compounds?

What are the qualities of platinum?

[illegible] malleability to gold and silver. It is very ductile, and takes a good polish. But the qualities which render it so useful, and in some cases indispensable to the chemist, are the extreme difficulty of fusion, being unaffected by any furnace heat, and the perfect manner with which it resists the action of almost all acids. It is acted on by chlorine and aqua regia, but less easily than gold, and is not affected by air. Platinum is about half as valuable as gold. Sp. gr. 22·5.

GOLD. (*Latin, Aurum.*)

Symbol Au, *equivalent* 98·33.

255. This is one of the most widely diffused of the metals, being found native in every country, generally in the form of minute grains, though sometimes in masses weighing several pounds. It has a brilliant yellow color and great density. It is so very malleable that it may be extended into leaves $\frac{1}{282000}$ of an inch in thickness, and so ductile that a single grain may be drawn into 500 feet of wire. It does not tarnish or oxidize when exposed to the air or heat, is affected by no single acid, and dissolved only by aqua regia (124). Its specific gravity is 19·2.

METALS COMBINED WITH EACH OTHER—ALLOYS.

256. Metals combine with metals to form alloys—an important class of bodies, as each compound thus produced may be looked upon, for all practical purposes, as a new metal.

257. *Brass* is an alloy of copper and zinc: four parts of the former to three of the latter. When the proportion of zinc is increased we have *pinchbeck*, or *Dutch gold*.

What is said of gold? What are its properties?
What are alloys? How may they be considered?
What is brass? Pinchbeck?

258. *German silver* is an alloy of copper, zinc, and nickel; the finer kinds containing most nickel. Bronze consists of 90 parts of copper to 10 of tin; gun-metal, 92 copper to 8 of tin; *bell-metal* and *gong-metal* of 80 parts of copper to 20 of tin. Britannia consists of about 100 parts of tin, 8 of antimony, 2 of bismuth, and 2 of copper.

259. The speculum of Lord Rosse's celebrated telescope is composed of 126·4 of copper to 58·9 of tin.

260. *Type-metal* is an alloy of 3 parts of lead and 1 of antimony. Pewter is composed of tin, with a little antimony, copper, and bismuth. The inferior kinds contain a good deal of lead.

261. Alloys which contain mercury are called *amalgams*. An amalgam of tin is used for silvering the backs of mirrors; and an amalgam of tin and zinc for exciting electrical machines. Gold and silver coin is alloyed with from $\frac{1}{10}$ to $\frac{1}{13}$ of copper, by which its hardness and wearing quality is greatly improved.

SALTS.

262. Salts are combinations of acids with bases (49). They are a very numerous class of bodies. We can here notice but few of them, and those very briefly. The common idea of a salt is that it must have a saline taste, like ordinary kitchen salt, and dissolve in water; but this notion is erroneous, as many salts have no taste at all, and are insoluble in any quantity of water, either cold or hot. There are two ways of classifying or grouping the salts—either by placing

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What is German silver? Bell-metal? Bronze? Britannia?

Type-metal? Pewter?

What are amalgams? What is said of coin?

What is a salt? What is the common idea of a salt? How is this wrong? How are the salts classified?

[illegible]gether those which have a common acid, or those which [illegible]ve a common base. I have adopted the arrangement of [illegible]r. Gregory, and classed together those derived from a common acid. The salts contain variable proportions of water, which are represented upon the Chart by the usual symbolic letters (H O), instead of diagrams.

SULPHATES.

PROTOSULPHATE OF IRON. (*Copperas, Green Vitriol.*)

$Fe\,O, S\,O_3 + 7\,H\,O$.—(*Silliman.*)

263. This salt, composed of sulphuric acid and protoxide of iron, is largely manufactured at Stafford, Vt., by the decomposition of iron pyrites, which furnishes, by oxidation, both the acid and the base (see Chart). It is used for dyeing dark colors, for making ink, and in medicine as a tonic in nervous diseases, and where the blood is supposed to be deficient in iron. It often exists in soils to a pernicious extent, but is decomposed by lime; gypsum or plaster being formed.

SULPHATE OF LIME. (*Plaster of Paris, Gypsum, Alabaster.*)

$Ca\,O, S\,O_3 + 2\,H\,O = 86$. Sp. gr. 2·3.—(*Graham.*)

264. This salt is easily made artificially, by dropping sulphuric acid upon lime. It occurs in many parts of the world, forming extensive rocky beds. It is so soft as to be scratched with the nail. The white varieties are turned in lathes, and worked with edge tools into various ornamental

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What is the composition of protosulphate of iron? For what is it used?
What is the composition of sulphate of lime? What are its common names? Where is it found? What is alabaster? What property adapts it for taking casts? What is stucco-work?

ganic acids (463), which are converted into carbonic acid by burning. It is usually more abundant in herbs than in shrubs, trees, or the grains, and abounds in the bark, twigs, and leaves, more than in the solid wood.

CARBONATE OF LIME. (*Limestone, Marble.*)

$Ca\,O, Co_2 = 50$; sp. gr. 2·9.—(*Graham.*)

276. Vast deposits of this salt are distributed all over the globe, in the form of limestones, marbles, chalks, marls, coral reefs, shells, &c. Carbonate of lime dissolves in water, containing free carbonic acid; hence the well and spring water of lime districts becomes impregnated with it, and is hard. When the hardness of water is due to this cause, it may be *softened* by the addition of lime-water, which neutralizes the excess of carbonic acid, and all the carbonate is precipitated.

277. *Animal Origin of Limestone.*—Numerous and extensive as are the limestone deposits, it is conjectured that they are all of animal origin. The densest limestone and the softest chalk are found to consist of the aggregated skeletons or shells of myriads of tribes of the lower animals, which have existed in some former period of the world's history.—(*Kane.*) The formation of coral reefs, which are sea-islands of carbonate of lime, built up from the depths of the ocean by minute aquatic animals, is an example of similar deposits now in process of formation.

What is the composition and equivalent number for carbonate of lime? When the hardness of water is owing to the presence of this substance, how may it be softened?

What is said of its origin?

CARBONATE OF AMMONIA—$NH_3 CO_2 + HO = 48$;

OR,

CARBONATE OF OXIDE OF AMMONIUM—$NH_4O, CO_2 = 48$.

278. When organic substances containing nitrogen, as flesh, and the liquid excretions of animals, decay or putrefy, carbonic acid and ammonia, an acid and a base, are simultaneously set free. These unite, and escape into the air as carbonate of ammonia. The elements of this salt are both gases, and the salt itself is a gas; but the alkali is so much stronger than the acid, that the compound still retains pungent alkaline properties. It was formerly procured by distilling the horns of harts; hence it was called *Spirits of Hartshorn.* The base of this salt is supposed not to be really ammonia, but an oxide of a peculiar compound, NH_4, termed *ammonium,* It has not been obtained separate, but is said to form an amalgam with mercury. According to this view, carbonate of ammonia becomes carbonate of oxide of ammonium, and muriate of ammonia chloride of ammonium.

HYDROCHLORATE OF AMMONIA. (*Sal Ammoniac, Muriate of Ammonia.*)

$NH_3, HCl = 53{\cdot}5$.

OR, CHLORIDE OF AMMONIUM. NH_4Cl.

279. Ammonia, saturated with muriatic acid and crystallized, forms an inodorous salt, sal ammoniac. It is used in soldering, to cleanse metallic surfaces, the muriatic acid dissolving the coat of oxide. Mixed with lime, which de-

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What is the equivalent for carbonate of ammonia? How is it produced? Why was it called spirits of hartshorn? What is ammonium?

What is the composition of sal ammoniac? For what is it used?

salt, while the meat is said to be equally savory and nutritious.

371. *White syrup* is the thick, oil-like solution of sugar in water. If this is set by, and allowed slowly to evaporate, the sugar gradually deposits itself (crystallizes) in the form of *sugar-candy*. The liquid sugar of honey is thus, after a time, deposited as a granular solid, forming candied honey. Candied sweetmeats are produced in the same way. When sufficiently heated, sugar becomes brown, loses its sweet taste, and acquires bitterness. In this state it is called *caramel*, or *burnt sugar*. When dissolved in water, it is used to color soups and sauces, and also various liquors.

OF THE ALBUMINOUS COMPOUNDS.

372. *Their Similarity of Composition.*—The bodies we have just been studying are associated in plants with another class of substances, less abundant, but equally important—the albuminous or nitrogenized compounds. They consist of the four organic elements, carbon, hydrogen, oxygen, and nitrogen (hence called *quaternary compounds*), together with a small quantity of sulphur and phosphorus, although it is too minute to be determined in atomic proportions; for this reason these substances are not represented upon the Chart. This group consists of albumen, gluten or vegetable fibrine, and caseine, all having the same chemical composition ($C_{48}\,H_{36}\,O_{14}\,N_6$).—(*Liebig.*) It has hitherto been assumed that these compounds contain, as basis, a common principle called *proteine*, hence they have been called *pro-*

What is white syrup? How are candied honey and candied sweetmeats produced? What is caramel? For what is it used?

What are the albuminous compounds composed of? Why are not the sulphur and phosphorus represented upon the Chart?

teinaceous compounds; but recent researches have rendered it doubtful if such a principle can be obtained.

373. *Vegetable Albumen.*—When the water which has been used to wash starch from wheat flour or rasped potatoes is allowed to stand until it becomes clear, and then boiled, it assumes a turbid appearance, and deposits a flaky, white substance, known as *vegetable albumen.* This substance is identical in composition and properties with white of eggs, and is named albumen from *albus,* white. When dried it forms a brittle, yellow, gummy mass. It dissolves in cold water, forming a glairy, tasteless, and nearly colorless fluid; but if heated to 160° it *coagulates,* that is, becomes solid, and will not again dissolve in water, either cold or hot. Liquid albumen is not only coagulated by heat, but also by alcohol, creosote, and corrosive sublimate. It is also coagulated by most acids, with which it unites as a base, forming definite compounds. Coagulated albumen is dissolved by the alkalies, towards which it acts as an acid, combining with and neutralizing them. Boiled eggs furnish a familiar example of coagulated albumen.

374. *Albumen easily putrefies.*—A most remarkable property of albumen is its instability, or tendency to decomposition. This is due to the complexity of its composition (316), as it consists of six elements and a large number of atoms ($C_{48} H_{36} O_{14} N_6 + S P$), and also to the fickle nature of its nitrogen (115). Dissolved in water, and at common temperatures, it is speedily broken up, and runs into putrefaction; this property is destroyed by coagulation. Decay in the starch group gives rise only to carbonic acid and water; but in albumen, in addition to these, hydrogen combines

How is vegetable albumen obtained? Whence does it derive its name? What are its properties? By what agencies is it coagulated? How do alkalies affect it? Why is albumen so unstable? What are the products of decay in this group?

peculiar acids, which emit a disagreeable odor. This change appears to result principally from minute quantities of nitrogenized organic tissues, which remain diffused through the fats. The rancidity of oleaginous bodies may be in a great measure removed by boiling them with water and a little magnesia, until it has lost the property of reddening litmus.

424. *How Unctuous Oils are Purified.*—As the drying oils are purified by oxide of lead, so the same change is produced in unctuous oils by sulphuric acid. We have seen (189) that this acid possesses the property of charring organic substances, but it does not act with equal energy upon all. When added to oil, it first attacks its nitrogenized and mucilaginous impurities: these are decomposed and precipitated. When just sufficient acid is used to effect this object, the mucilage alone is charred; if too much, the oil itself is decomposed.

425. *Olive Oil, or Sweet Oil.*—This oil is obtained by pressure from the fleshy or pulpy part of the fruit of the olive-tree. The finest kind is of a yellowish color, has a thin consistence, a slight odor, an agreeable taste, and when swallowed leaves a very slight sense of acrimony in the throat. When pure it has less tendency to change than almost any other of the fat oils, but the inferior qualities soon become *rancid*. It contains 72 per cent. of oleine and 28 of margarine, the latter of which congeals in cold weather. Being less apt than most other oils to thicken by exposure to air, it is preferred for greasing delicate machinery, especially watch and clock work. It is used at table as a condiment for salads, and is hence termed *salad oil.* In Spain it is used as

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What are the unctuous oils? For what are they used? What is rancid oil? What causes the change? How may it be removed?

What is the effect of sulphuric acid upon the unctuous oils?

How is olive oil obtained? What are its properties? For what is it used?

a substitute for butter. Taken in large quantities, it acts as a mild laxative.

426. *Palm Oil* is a solid butter-like oil, of an orange-yellow color, obtained by pressure from the fruit of the palm-tree. It is readily blanched by heat, or the joint action of air, light, and moisture, and also by chlorine. It contains 70 per cent. of oleine and 30 of stearine, and is used in the manufacture of soap and candles. *Oil of almonds* is expressed from sweet almonds; also from bitter almonds by cold pressure, as if heat is employed the oil contains prussic acid. It is mainly used in liniments, ointments, and soap. Unctuous oils are also obtained from *rape-seed, beech-nuts, hazel-nuts,* and the stones of fruits.

ANIMAL FATS.

427. These are contained in the bodies of animals, in what is termed *cellular tissue* or *adipose membrane.* They are obtained by a heat sufficient to liquefy the fat, and burst the including cell, or sack. The more solid portion of the fat (stearine) forms a layer next to the inner surface of the cell-membrane, the softer part (oleine) being inclosed within. Fat forms about one-twentieth the weight of a healthy animal.

428. *Mutton Tallow.*—This is a very white and solid fat. It has little odor when fresh, but acquires a peculiar, rancid smell, when exposed for some time to air.

429. *Beef Tallow* is of a yellowish-white color, firm, and yields 75 per cent. of stearine to 25 of oleine.

430. *Neat's-foot Oil* is obtained from the feet of oxen, by

What is palm oil? What is said of the oil of almonds?
In what part of animals is the fat deposited? How is it obtained?
What is said of mutton tallow? Beef tallow?

Indeed, the maintenance of animal life is only possible by the perpetual waste and destruction of the organism by which it is manifested. In the passage of constituent particles from the living to the dead state, consists the life and power of the individual. Were this process of dying by atoms, in a measured and regulated way, suddenly to cease, the death of the whole system would be the consequence. It is usually said that dead animal matter is marked by its necessary tendency to decay, while the living body is distinguished by its power of *resisting* decay. But so far is this from being true, that the very opposite is the fact. The fixed condition of the continuance of life in an animal is the decomposition which all its parts constantly suffer, while dead animal matter may be preserved, it is well known, for almost any length of time unchanged. Meat, by partially cooking and sealing up free from air, may be kept sweet even in the moist state for years. Cold also arrests decay. In Russia, animals are long kept in the market in a frozen state, and their flesh, when thawed, is as good as ever.

492. *Reparative Power of the Living Being.*—But in one very important respect the living mechanism differs from the inanimate machine; the latter has no ability to repair the destruction it suffers by use. There is no inherent power in a watch or a steam-engine to restore its wasted parts; action goes forward until checked by loss of substance and consequent derangement, when the combination is handed over to the mechanic for reconstruction. The living body, on the contrary, is endowed with a capacity of self-renovation. It can repair its failing tissues, and counteract its own constant tendency to ruin. The process by which this renewal takes place is called *nutrition,* and the substances employed to carry it on constitute *food* or *nutriment.*

In what respect does the living body differ from the inanimate machine?

By means of food, therefore, the living organism can compensate the rapid expenditure of its own substance, restore its losses, and maintain its power.

493. *Supply of Matter to the Plant.*—This process of nutrition is accomplished by different methods in the two great departments of organic life. The plant is fixed to one spot, and has no power of changing its locality. Its roots penetrate the soil to a limited distance, and its leaves are spread through the air. Within this narrow space it finds the elements necessary to its growth. Water, with mineral salts, and gases extracted from the earth and atmosphere, constitute its food. If these happen to abound, the plant exhibits a condition of high activity, a rapid and luxuriant growth; if this supply is deficient, development is correspondingly feeble and imperfect. The simple object of the plant is to *grow,* and form various proximate substances. It is hence found in immediate connection with the sources of its nourishment, and there remains throughout the whole term of its life.

494. *Mode in which Animals are supplied with Matter.*—The case is different with animals, especially the higher classes. They are organized for the accomplishment of other purposes besides bare vegetative development, and the nutritive operations are so carried on as not to interfere with the higher functions. Having the power of locomotion, by which it is capable of moving from place to place, the animal is supplied with a cavity (stomach), into which it receives a store of food sufficient to last it for a considerable time, independent of a supply from any external sources. From this cavity the system is gradually supplied with nutritive mat-

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To what conditions is the plant confined?
How do the conditions of nutrition in animals differ from those of plants?
What constitutes a fundamental distinction between animals and plants?

life of a plant in which it exercises the heat-evolving function, and becomes independent of surrounding temperature. In the germination of seeds, as we have seen ([illegible]), there is a development of heat, and the same thing occurs during the act of flowering. Thus a thermometer, placed in a bunch of flowers of the Arum, rose to [illegible] when the temperature of the air was but [illegible]. Now in both these cases there is an absorption of oxygen, which unites with the sugar of the flower and the oil of the seed, and a liberation of carbonic acid in exact proportion; and that the heat is simply due to oxidation, is proved by the fact that, if the presence of oxygen is prevented, no heat is evolved; whereas if pure oxygen gas is employed, the liberation of heat is more rapid than usual. The effect, in this case, cannot be due to nervous action, for plants have no nervous system. The production of heat in the animal body is *under the control* of the nervous system, precisely in the same manner that the fire which drives a steam-engine is under the control of the stoker or fireman: but he certainly cannot be considered as the source of the fire—as producing the heat—but only as its regulator: he may extinguish the fire, or increase it, and in the same manner the nervous system influences animal heat.

[illegible]. *Animal Temperature regulated by Evaporation.*—It has been stated that the temperature in man, except in cases of disease, never rises higher than about 98° F. It is kept down to this point by the cooling effect of evaporation, which takes place from the surface of the skin. This organ is penetrated by a vast number of minute tubes (about 700 inches of tubing to each square inch of skin-surface), by which wa-

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thus shown to be erroneous? At what two periods is heat evolved by plants? What chemical changes occur? How is it proved that the heat is due to oxidation? Why can it not be ascribed to nervous agency? In what sense may the production of heat in the body be controlled by the nervous system?

By what means is the heat of the system kept down to 98°? How is the skin ter (perspiration) is poured out and evaporated, thus carrying away the surplus heat from the body. The amount of fluid which escapes from the skin, as *insensible perspiration*, is estimated at 11 grains, and that from the lungs seven grains per minute. The power which men have exhibited of enduring excessive heat, for a short time, is due to the increased activity of surface-evaporation.

581. *Office of the Liver.*—If more respiratory food is taken into the system than is consumed by respiration or deposited as fat, it is separated from the blood by the liver. A special channel (*portal circulation*) carries the venous blood through this organ, where its surplus hydro-carbon (*fatty matter, bile*) is strained out. If too much work is thrown upon the liver it becomes disordered, and the substances which it should draw off accumulate in the blood, producing various symptoms, generally known as *bilious*. This is quite liable to happen in warm climates, when the elevation of the external temperature, combined with the want of sufficient exercise to stimulate respiration, leaves the non-nitrogenized elements of food unconsumed in the system. A similar disordered condition of the liver sometimes results from a diseased state of the lungs, by which they are rendered incapable of furnishing the due amount of oxygen for the combustion of the respiratory food. The office of both lungs and liver is to relieve the blood of excessive carbon: their functions are thus complementary; that is, when the action of one increases, the other diminishes. It is observed that, throughout the whole animal series, the development and activity of the respiratory organs stands in an inverse proportion to that of the

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adapted for this process? What is the amount of insensible perspiration? How have men been enabled to endure excessive heat for a short time?

What is the office of the liver? How are bilious symptoms produced? Where are they the most frequent? What other cause sometimes produces disease of [illegible] there is a corresponding [illegible] season of rest and unin[illegible] required for the complete restoration [illegible]

[illegible] BY THE KIDNEYS.

[illegible] *Waste.*—The separation from [illegible] and expulsion from the system of those substances which cannot remain without detriment, and which [illegible] purpose in the animal economy, is termed the [illegible] *excretion.* The peculiar products of muscular and [illegible] decompositions are to be found in the renal excretions [illegible] which pass from the system by the channel of [illegible] The nervous substance contains a large pro[illegible] phosphorus (545), a substance which [illegible] considerable quantity in the other tis[illegible] this is converted into phosphoric acid, [illegible] the alkalies, soda, and ammonia, and in [illegible] of the system in the liquid excretions. [illegible] found that the amount of the alkaline [illegible] these excretions bears an imme[illegible] intensity and duration of mental exer[illegible] Any unusual strain or wear [illegible] followed by an increase in the propor[illegible] voided by the kidneys.

[illegible] *of Muscular Waste.*—When the muscu[illegible] broken up by oxidation, the large share of [illegible] nitrogen combines with hydrogen, giving [illegible] As ammonia is a very caustic sub[illegible] irritate and inflame the delicate [illegible] is required to pass, it is united

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[illegible] excretion? What relation is said [illegible] by the kidneys?

[illegible] removal of ammonia from the system?

with carbonic acid, which is formed at the same time, but not in such a way as to produce carbonate of ammonia, which would also be injuriously corrosive. Instead of this acrid salt, nature with admirable care produces an inert and perfectly harmless compound, known as *urea*. The composition of this substance is $C_2 H_4 O_2 N_2$, which, it is seen, would form carbonate of ammonia by the addition of two atoms of water. The same process of oxidation which gives birth to the elements of urea, also forms sulphuric acid (from the sulphur contained in the muscular tissues), which is neutralized by alkalies, and separated, together with urea, from the arterial blood by the kidneys. The amount of sulphates thus formed may be taken as a measure of the waste of the muscular tissues, and consequently of the degree to which they have been exercised.

594. *Nature of the Renal Excretion.*—The kidneys are devoted to the excretion of all those waste matters of the system which are soluble in water; eleven-twelfths of the nitrogen is estimated to pass out by this route in the form of urea, together with most of the salts, both earthy and alkaline, which have taken part in the vital processes. When more nitrogenized food is consumed than is required to supply the waste of the tissues, the surplus is carried off by the kidneys, which are thus made to perform more than their proper duty, and often become diseased. About 7 per cent. of solid matters may be separated from the urine, 3 of which are urea. A very small proportion of an albuminous substance is also present, which, when exposed to the air, speedily ferments and communicates its action to urea, which is changed to carbonate of ammonia by the addition of two atoms of water, giving rise to two atoms of the carbonate from one of urea. The liquid excretions of animals,

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Of what do the renal excretions consist? Why are their products supposed to be very serviceable in the growth of plants?

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